BBC **RICHARD DAWKINS** ON FAITH, FLAT-EARTHERS AND FACEBOOK

Science Focus

NOT JUST ANOTHER MICKEY MOUSE PLANET

Why there's no
OVERPOPULATION CRISIS

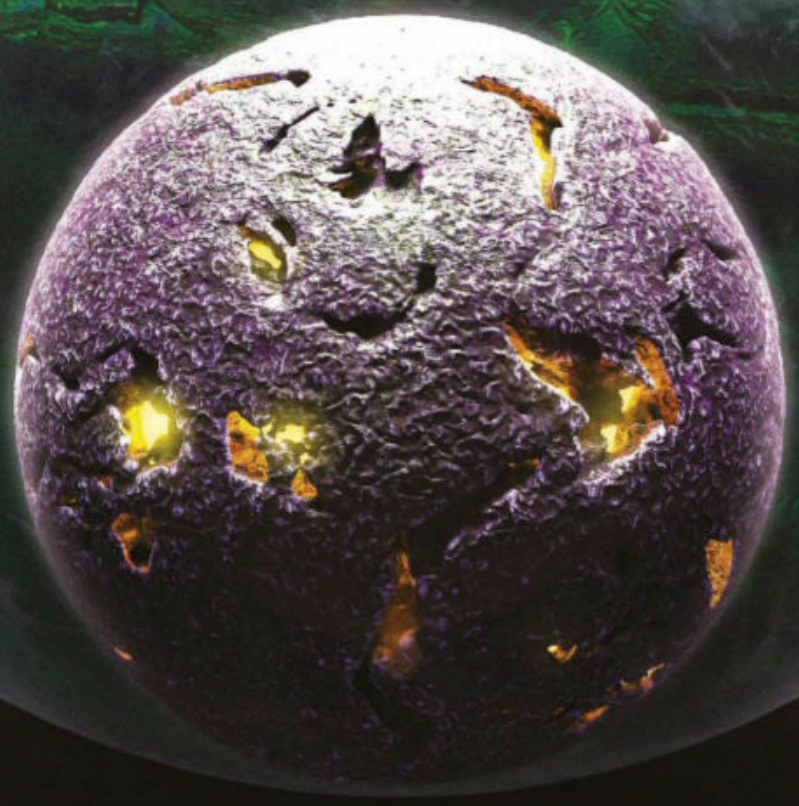
How chocolate
BOOSTS BRAIN HEALTH

Should we rethink
SHOCK THERAPY?

THE NEW SOLAR SYSTEM
SPECIAL REPORT

THE HUNT FOR
PLANET 9

How we'll find the most mysterious object in our Solar System



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SEPTEMBER 2019

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SENSATIONAL
SIX

ALL-ROUND CREATIVE GENIUS

tech radar EDITOR'S CHOICE ★★★★★ | Digital Camera World ★★★★★ | N Photo GOLD AWARD ★★★★★ | Amateur Photographer AWARD WINNER 2019 | Trusted Reviews HIGHLY RECOMMENDED ★★★★★ | T3 WINNER AWARDS 2019 Best Camera Nikon Z 6 | TIPA WORLD AWARDS 2019

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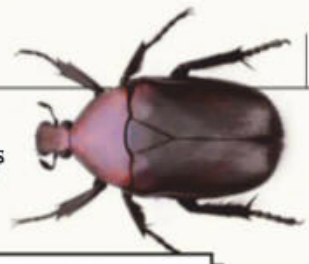

Why do some insects look metallic? →p87

FROM THE EDITOR

In astronomy, the horizons are changing all the time. Bigger, more sophisticated telescopes and increasingly inventive imaging techniques continually redefine how much of our Universe we can see. In recent years we've discovered hundreds of Earth-like planets nestled in distant galaxies, witnessed neutron stars crash into to each other and even got up close and personal with a black hole.

In these terms, it seems odd to think there might be an undiscovered planet lurking beyond Pluto, let alone one that might be four times bigger than Earth. After all, Neptune was discovered in 1846, and Pluto, though it isn't considered a planet, was identified in 1930. How is that this shadowy world has evaded our gaze for so long? Find out on p50, where Colin Stuart reports on the discoveries about to be made at the edge of our Solar System.

And finally, back on Earth, we met the affable Dean Burnett this month, ahead of the release of his latest book. If you're one of our teen readers, then head to p90 where Dean explains why the world ought to spend a little more time listening to you...

Enjoy the issue!

Daniel Bennett, Editor

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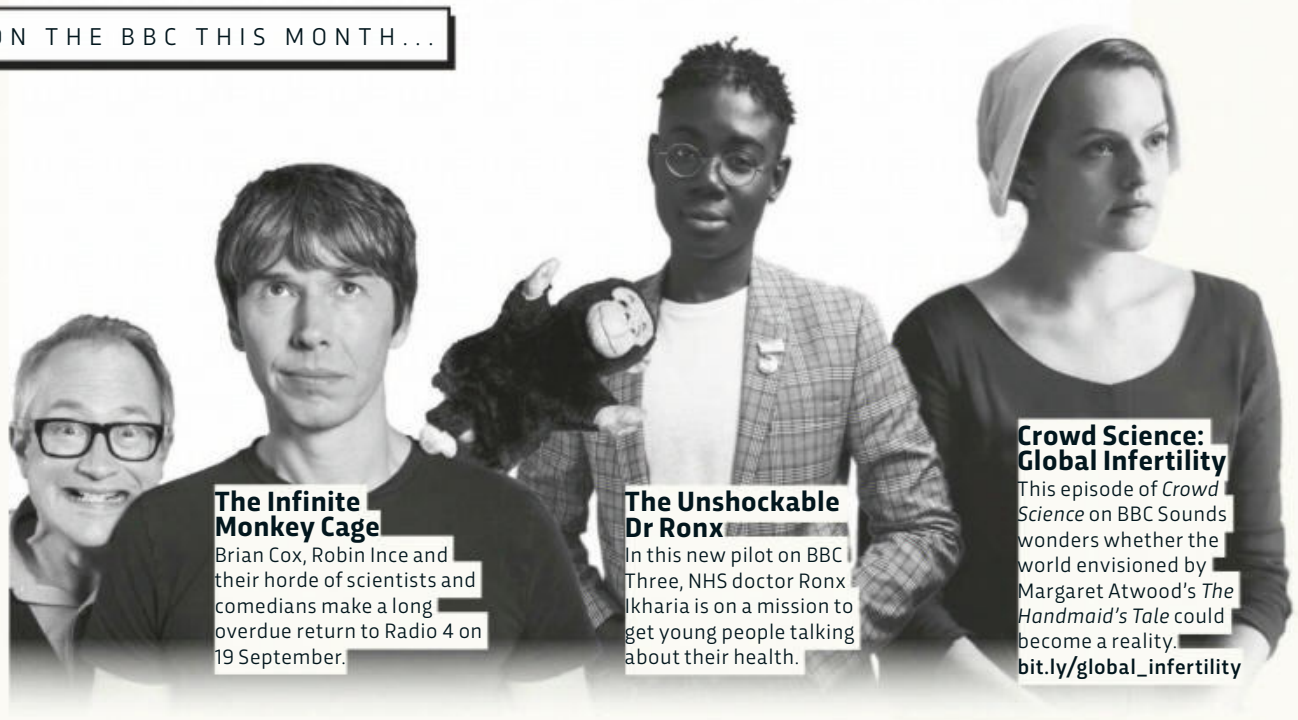
ON THE BBC THIS MONTH...



The Infinite Monkey Cage
Brian Cox, Robin Ince and their horde of scientists and comedians make a long overdue return to Radio 4 on 19 September.

The Unshockable Dr Ronx
In this new pilot on BBC Three, NHS doctor Ronx Ikharia is on a mission to get young people talking about their health.

Crowd Science: Global Infertility
This episode of *Crowd Science* on BBC Sounds wonders whether the world envisioned by Margaret Atwood's *The Handmaid's Tale* could become a reality.
bit.ly/global_infertility

COVER: MAGIC TORCH THIS PAGE: BBC, CHRISTA HOLKA, ALAMY

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JOCELYN TIMPERLEY
As the global population surges towards eight billion, climate and energy journalist Jocelyn looks at whether having fewer children can really make a difference. → p74

ABIGAIL BEALL
What will cities of the future look like? Science and tech journalist Abigail reveals the plans to move people into the trees, onto the oceans, and deep underground. → p42

HELEN GLENNY
Electroconvulsive therapy is shrouded in controversy and misunderstanding. Science writer Helen explains why it might be time to rethink this potentially life-saving therapy. → p68

DARREN NAISH
Everyone has a story about gulls eyeing up their lunch, but are the birds getting bolder? Zoologist and science writer Darren investigates whether they are really a menace. → p38

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> “The real reason why I’m opposed to religion is that it stunts the understanding of the wonderful Universe in which we live”

WANT MORE?

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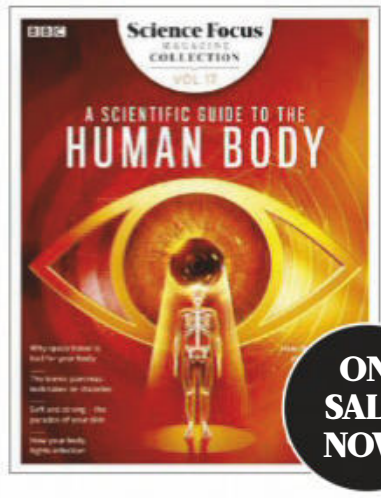
Can’t wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied.
sciencefocus.com

SPECIAL ISSUE



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EYE OPENER

Drone down

PARIS, FRANCE

Looking rather like props from an action film, these NEROD F5 devices are actually high-tech drone jammers, designed to scramble the signal of an enemy unmanned air system (UAS).

On 14 July, this demonstration of the NEROD F5 stunned crowds at the Bastille Day parade in Paris. When the trigger is pulled, the gun fires microwave-frequency signals towards the drone, which then disrupts any communication between the drone and its pilot. This means the pilot can no longer direct the drone.

The rifle-style design of the NEROD F5 is unlike most drone scramblers, which usually require a large battery that is worn in a backpack by the operator. Other methods of bringing down drones include sending a false GPS signal to the drone, which confuses its sense of direction and positioning, or distracting a drone's camera with a laser beam.

REUTERS

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EYE OPENER

Surface tension

INGLEFIELD FJORD,
GREENLAND

Climate scientist Steffen Olsen took this photo as he travelled across sea ice in Greenland to retrieve instruments in a remote weather station. The ice, hardened by the long winter, has very few cracks. So, when the surface begins to melt, there is nowhere for the water to drain and it collects as a huge lake atop the fjord. Olsen makes this journey every year, in early June, at a time when the ice is usually still intact. This year, however, Greenland experienced extreme temperatures.

"This was an unusually early melt event," says Olsen. "The ice completely broke up just a few days after this photo. We have recorded the date that the ice breaks up for 100 years, and it has only happened earlier than this once."

Next year, Olsen will make the same journey. He hopes that climate change does not push the melting of the sea ice any earlier.

STEFFEN M OLSEN/DMI

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

As I say, not as I do

I picked up your magazine in a dentist waiting room and I think you have got yourself a new reader! As someone who has been promoting breastfeeding for over 20 years, I was really excited to read your article on the special components of breast milk (June, p20). With regards to your article on 'biohacking' (June, p33): the famous doctor Maimonides was already writing about overeating in medieval times. His thesis was very much that the right kind and right amount of food was the key to good health and longevity. I was going to end this letter thanking you for explaining why I go through a whole bag of caramels in one go (June, p85)... but in view of what I wrote above about eating the right amounts of foods, I think it would be better if I did not expose myself so!

Maria Luck, *via email*

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins **three Neos SmartCams**. The pocket sized, Alexa-compatible SmartCam allows families to protect and monitor their homes from wherever they are in the world, through a smartphone app. It automatically starts recording when noise or motion is detected, making it easy for homeowners to keep an eye on their house or pets while they're away. **neos.co.uk**

WORTH £60

Support UK research

I was very interested in your article 'What's up, dog?' (May, p24) but looking into the subject further I found I was disappointed. Why? Well, the article was based around the work of BioScentDx, a company in Florida. I readily found an organisation in the UK, the Medical Detection Dogs, who train 'bio-detection dogs' and 'medical alert assistance dogs' on a non-commercial basis. I would politely suggest that UK journals and magazines such as *BBC Science Focus* should concentrate more on highlighting, and therefore supporting, the work of UK research bodies, and especially those that are charitably based.

David Tordoff, *Shropshire*

In our *Discoveries* section we try to cover the most interesting and up-to-date research from around the world, so inevitably we will sometimes cover a piece of research from a foreign team that is similar to work being done in the UK. However, we do try our best to champion UK research whenever possible. We actually covered a story on the Medical Detection Dogs sniffing out diseases in the Summer issue of *BBC Science Focus* (p73), for example.

We will definitely be keeping an eye on the work of Medical Detection Dogs UK for future developments.

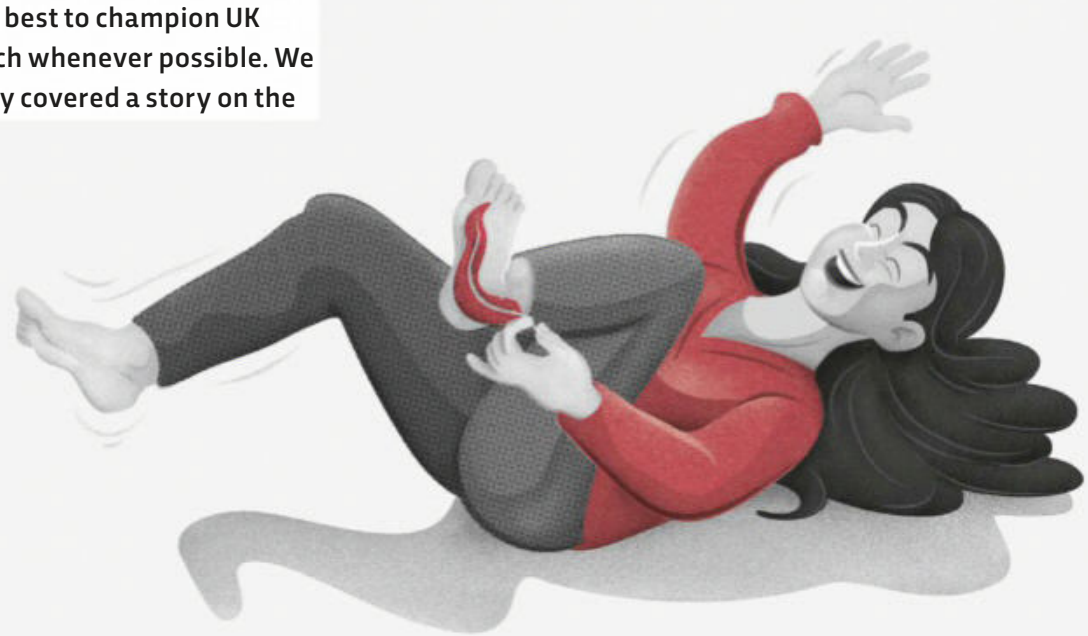
Jason Goodyer, *commissioning editor*

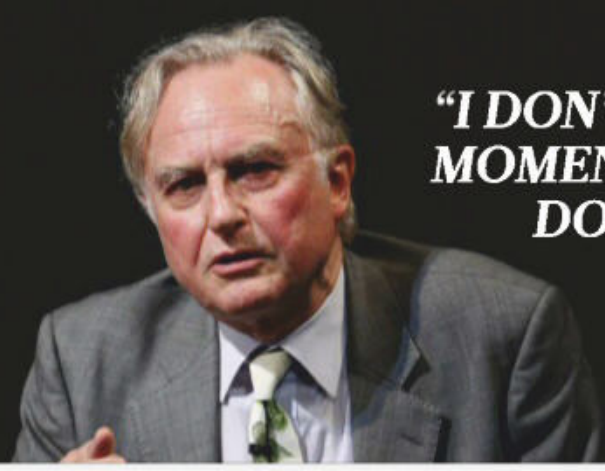
Tongue tickles

In response to Luis Villazon's answer to Toby Graham's question about why it's impossible to tickle yourself (Summer, p87), it *is* possible to tickle yourself! Close your mouth and gently flick your tongue on the roof of your mouth and you will get a tickling sensation.

Martyn Garthwaite, *Chingford*

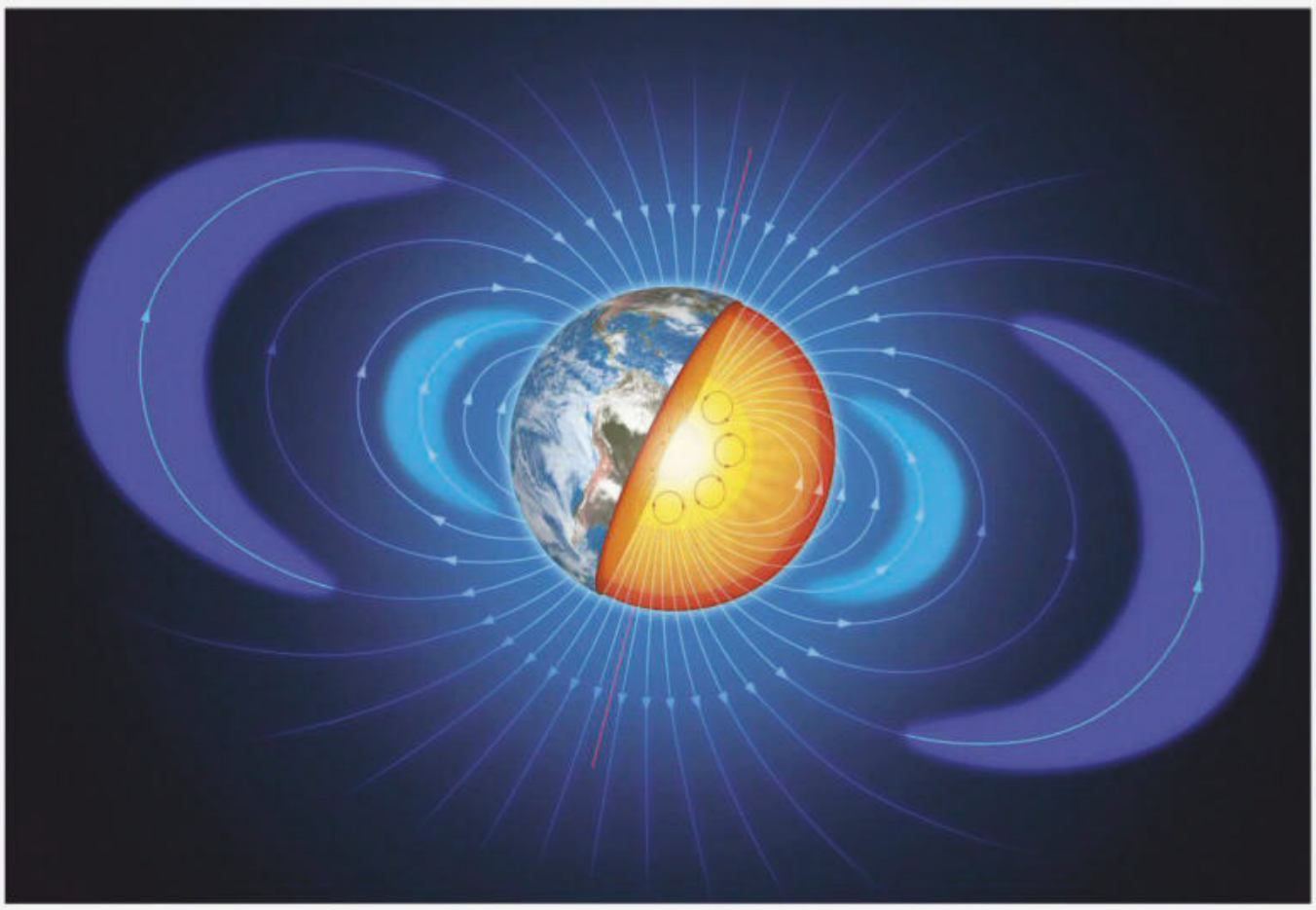
Yes, you can tickle yourself, says Martyn Garthwaite... just not with a feather





"I DON'T FOLLOW ANYBODY AT THE MOMENT, BECAUSE I NO LONGER DO TWITTER MYSELF. IT'S DONE FOR ME, I DON'T EVEN HAVE MY OWN PASSWORD"

RICHARD DAWKINS, p62



The Earth's Van Allen radiation belts, visualised here by bright blue and purple areas

GETTY IMAGES X2, SCIENCE PHOTO LIBRARY

Radioactive, radioactive

Having read your article on proving the Moon landing (Summer, p65), there was one area quoted by conspiracy theorists that was not touched: radiation. As this is one of the main arguments against the flight and landing, was this deliberately ignored? Is there no proof that astronauts could survive the radiation?

Michael Stockford, *via emaiL*

You're right that radiation was a potential danger. In particular, the Van Allen radiation belts are streams of high-energy particles from the Sun that have become trapped in the Earth's magnetic field. Spacecraft in low Earth orbit circle beneath them, but anything heading further afield must pass through this hazardous zone.

NASA was well aware of the risk, and consequently the Apollo missions took trajectories that minimised their time in the belts and avoided the densest regions. Plus, the spacecraft hulls provided the astronauts with some degree of shielding. All told, each Apollo 11 crew member soaked up radiation to the tune of about two-fifths the annual ambient dose received by a human on Earth. In other words, not very much. Certainly nothing to worry about.

Paul Parsons, *science writer*

"THE SPACECRAFT HULLS PROVIDED THE ASTRONAUTS OF THE APOLLO 11 CREW WITH SOME DEGREE OF SHIELDING"

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OPTIK

MARS MISSION
The Rosalind Franklin rover preps for launch p28

MOVIES FOR CHIMPS
Scientists run a film night for primates p15

DISCO SHARKS
Secrets of glow-in-the-dark sharks revealed p18

CLOSE CALL
All the near-Earth objects visualised p20

DISCOVERIES

DISCOVERED: THE CHEMICAL THAT MAKES MEMORIES

Your brain has its own box of memories. If you were to hold it in your hand, brush off the dust and open it up, you'd be able to pull out Polaroid snaps of your most treasured memories. Your graduation ceremony perhaps, your wedding day, your child's first words – all things you wouldn't want to forget. But how does your brain keep these memories in their crystal-clear clarity?

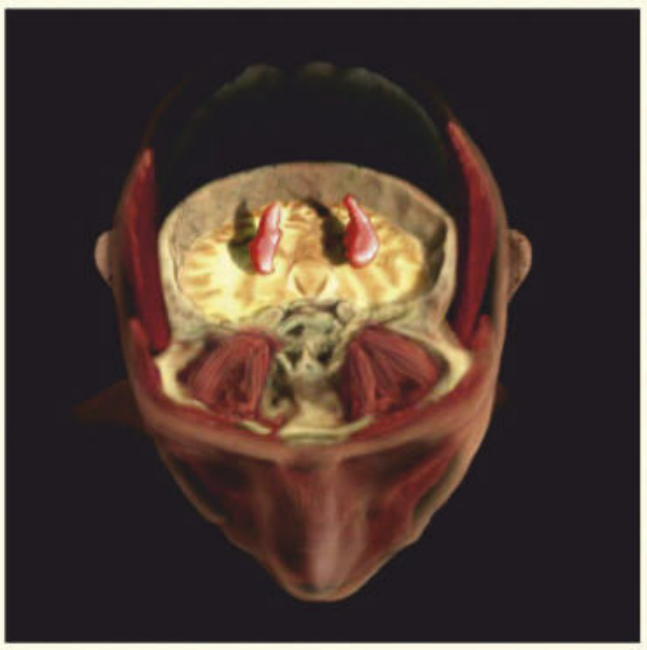
The synapse between two nerve cells (illustrated here) plays a vital role in memory formation

SCIENCE PHOTO LIBRARY, GETTY IMAGES

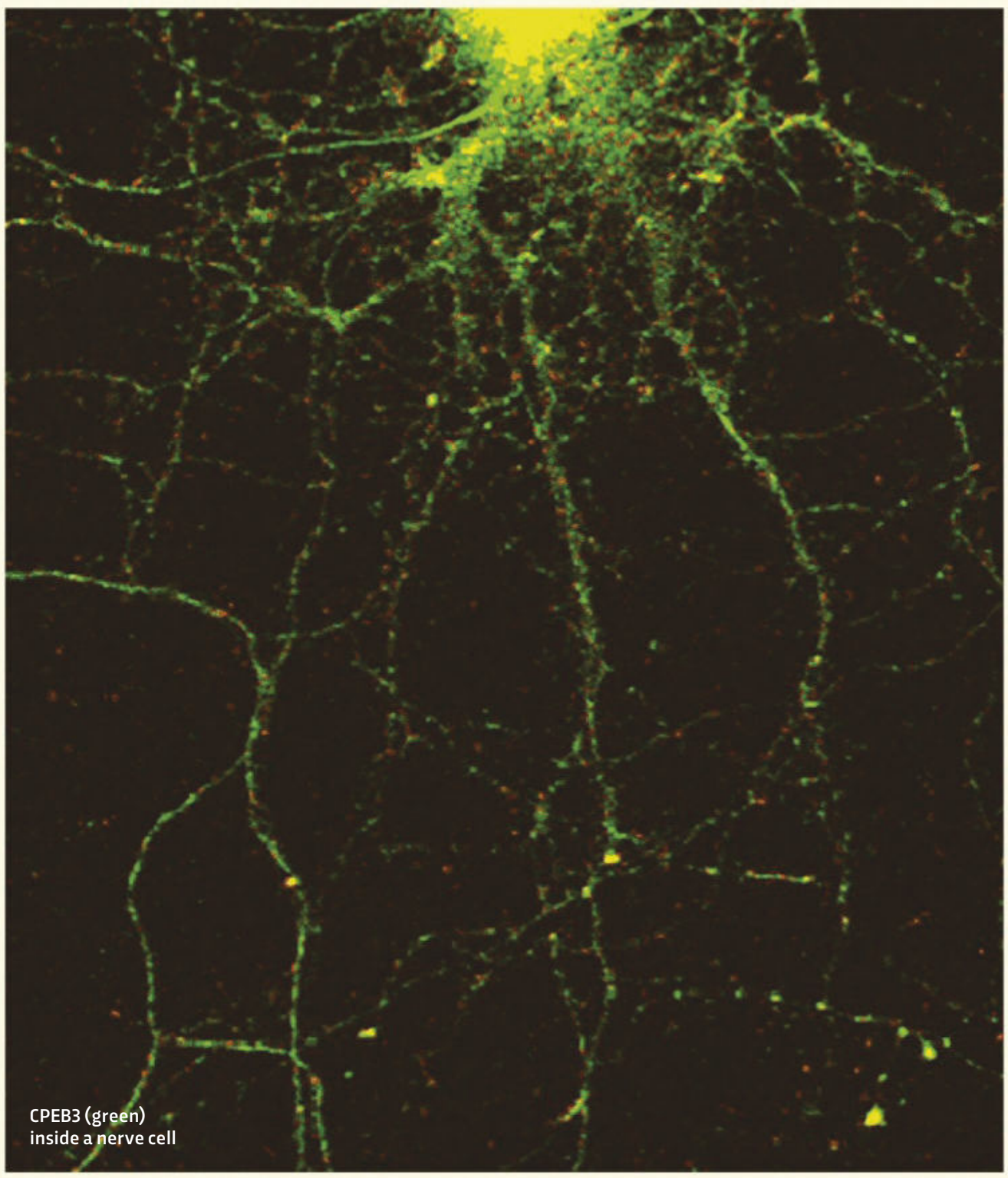
News in brief

MULTITASKING JUST AS HARD FOR WOMEN AS MEN

One of the great gender myths has, it seems, been busted for good: new research shows that men and women are equally good (or bad) at multitasking. Psychologists in Germany tested the multitasking prowess of 48 men and 48 women, using letter and number identification tasks to measure the participants' ability to pay attention to two tasks at once (concurrent multitasking), or to switch attention between tasks (sequential multitasking). Multitasking had a negative effect on both the participants' speed and their accuracy, but there was no difference in performance between the men and women.



The protein CPEB3 is created in the hippocampus (red kidney-shaped areas)



CPEB3 (green) inside a nerve cell

SCIENCE PHOTO LIBRARY, GETTY IMAGES, CARNEGIE MELLON UNIVERSITY

The strength of a memory lies in its formation and upkeep. When we create a memory, the axons of nerve cells in the brain connect. The point at which two axons connect is called a synapse, and it is the strength of the synapse that determines if the memory is stored or allowed to fade away.

Now, a study in mice carried out by Nobel Prize-winning researchers at Columbia University has shown that a protein called CPEB3 plays an important role in the formation of memories. The team discovered how this protein is stored and used in the brain and hope it could lead to new methods of slowing memory loss in humans.

"The science of how synapses form and are strengthened over time is important for deciphering any disorder in which synapses – and the memories associated with them – degrade and die, such as Alzheimer's disease," said Dr Luana Fioriti, who co-authored the research.

CPEB3 is created by the brain's memory centre, the hippocampus. Once produced, it is stored in structures called P bodies that protect it from other parts of the cell. It then travels to the synapse between nerve cells where required and is gradually released to help create a specific memory.

The findings suggest that the more CPEB3 is released at a synapse, the stronger the connection and thus, the more concrete the resulting memory will be. When the protein was removed, the mice could create new memories but were unable to keep them. As a version of CPEB3 can be found in human brains, this discovery represents a promising new avenue for research into memory loss.

"Memory is what makes us who we are. It permeates our lives and is fundamental to our very existence," said Nobel Laureate Dr Eric Kandel, who co-authored the research. "But at its core, memory is a biological process, not unlike a heartbeat. With this study, we've shed new light on the molecular underpinnings behind our brain's ability to make, keep and recall memories over the course of our lives," he added.

STONE AGE HUMANS GORGED ON GIANT RATS TO SEE THEM THROUGH THE ICE AGE

Times were hard for the Stone Age inhabitants of the Bale Mountains of Ethiopia. So hard, in fact, that the plummeting temperatures of the Ice Age forced them to exist on a diet of giant mole rats, which were plentiful. Excavations of the Finch Habrea shelter, located 3,350m above sea level, have discovered stone artefacts, bits of pottery, and piles of giant rat bones (pictured right). Carbon dating suggests the artefacts are between 47,000 and 31,000 years old making the site one of the oldest high altitude settlements ever discovered.

MEDICINE

Printed hearts take shape

The dream of 3D printing whole, living human hearts for lifesaving transplants just got a little closer. A team at Carnegie Mellon University in the US has developed a technique to 3D print collagen in fine detail. Collagen, besides being the most abundant protein in the body, is a key structural element that forms the biological scaffold that gives organs their structure and strength.

Carnegie Mellon's new technique, called Freeform Reversible Embedding of Suspended Hydrogels (FRESH), deposits collagen, layer by layer, within a support bath of gel. This enables the collagen to solidify in place as the complex structure is built up. When the printing is complete, the support gel is melted away by gently heating it to 37°C – body temperature. "If you try to print this [collagen] in air it just forms a puddle on your build platform. So we've developed a technique that prevents it from deforming," said Andrew Hudson, who co-authored the research.

The technique can print filaments as narrow as 0.02 millimetres across – around the width of a human hair. This enables researchers to print detailed structures into which living cells can be deposited to build muscle and blood vessels.

"What we've shown is that we can print pieces of the heart out of cells and collagen into parts that truly function, like a heart valve or a small beating ventricle," said Prof Adam Feinberg, a biomedical engineer at Carnegie Mellon University. "By using MRI data of a human heart, we were able to accurately reproduce patient-specific anatomical structure and 3D-bioprint collagen and human heart cells."

The FRESH technique will also work with other bio-inks that, like collagen, are soft when first printed, so the team hopes it will provide a highly adaptable tissue-engineering platform. They have also made the design of their system open source, so that other groups can use them to build 3D bioprinters at relatively low cost.

LENZIE FORD/LUANA FIORITI/KANDELL LAB/ZUCKERMAN INSTITUTE AT COLUMBIA , GOTZ OSSENDORF ILLUSTRATION: GABRIEL SILVERA

Collagen is difficult to work with in 3D printing as it starts out as a fluid. This new technique prevents it from deforming, so body parts – like this heart valve – can be made

They did what?

Chimps sent to the movies

WHAT DID THEY DO?
Researchers from Duke University paired up chimpanzees and had them watch a short movie. After the cinema session, they then observed their behaviour, taking note of how long it took the two apes to approach one another, how close they got, and how long they stayed together, and compared them to pairs of chimps that had watched movies alone.

WHAT DID THEY FIND?
The chimps that watched movies together approached one another more readily and spent more time together than those who had watched movies on their own.

WHY DID THEY DO THAT?
The team wanted to investigate the effect of shared experiences on social bonding. Humans have a wide variety of social activities that brings them closer together, such as listening to music, dancing, or watching films. Although only preliminary, this study suggests that apes may display similar behaviour indicating that the act of bonding through shared experiences may have deeper evolutionary roots than previously thought.

THE TERRIBLE TEENS AREN'T LIMITED TO HUMANS

As anybody who has lived through them can attest, the teenage years can often be a time of heightened impulsivity, sensation-seeking and questionable choices. Now, researchers at the University of Pittsburgh have found that macaque monkeys go through a similarly difficult period during puberty. These changes in the transition to adulthood are likely to be essential for both humans and animals to explore and gain new experiences, the researchers say.

Trending

YOUR GUIDE TO WHO'S SAYING WHAT ABOUT THE HOTTEST TOPICS IN THE WORLD RIGHT NOW

#WorldLizardDay

14 August marked this year's World Lizard Day – a global celebration of all things lizardy.

Liam Russell
@liam_agilis

#WorldLizardDay #sandlizards are found in 3 areas of the UK, heathland in Surrey and Dorset and sand dunes in Merseyside. Dune animals differ in colour and pattern.

ZSL London Zoo
@zsllondonzoo

Happy #WorldLizardDay from Ganas! #DYK, Komodo dragons are the largest living lizards in the world? #WildlifeWednesday #WildlifeFacts

IOP Publishing
@IOPPublishing

Join us to celebrate #WorldLizardDay with research exploring the adhesive systems and load-sharing that occurs in gecko toes in the journal @BioinspBiomim by researchers from @StanfordEng and @TU_Muenchen (**bit.ly/lizard_toes**)

#GretaThunberg

Climate change activist Greta Thunberg is heading across the North Atlantic on a boat to attend a climate change conference in New York. The journey will take her two weeks.

Masum Khwaja
@masumkhwaja

Greta is only 16 years old and she has already achieved more in her life to date than those 'normal adults' abusing her online are likely to achieve in their lifetimes. #gretathunberg

Marwa
@marwaazelmat

The @GretaThunberg movement should not only remind world leaders of the climate crisis, but it should also call upon enabling spaces to other young women and men from different backgrounds and geographical confines. #Climatechange does threaten everyone's survival.

#GayPenguins

Skipper and Ping, a pair of gay king penguins at Berlin Zoo, have been given an egg to hatch after it was abandoned by the only female king penguin in the zoo.

Baldowines
@baldowines

They could be having holidays vacation in exotic places for the rest of their lives; but no, they choose to be heteronormative. Now they are slaves til that chick goes to college. #gaypenguins

LGBTed
@LGBTedUK

Homosexuality exists in many species, but homophobia exists in only one. #FreedomToLive #gaypenguins #lgbted

KEEP IN TOUCH

@SCIENCEFOCUS

#Ebola

A cure for Ebola has been developed by Prof Jean-Jacques Muyembe in the Demographic Republic of Congo.

Sangwe, MD (The Rural Doctor)
@TheRuralDtor

Tomorrow, let's not forget that the cure for Ebola was made by an African. Thank you!

Mimo
@mimoyd1

African researchers and doctors have been in the vanguard on Ebola for a long time. They deserve far more credit than they usually get from outsiders.

The team tested their method using data from Campi Flegrei, near Naples

GETTY IMAGES X3, REUTERS, HELMHOLTZ CENTRE

NATURAL DISASTERS

Scientists develop new method to help predict volcano eruptions

Computer model applied to data from Italian volcano correctly forecasted the location of historic vents

When volcanoes erupt, the magma doesn't always shoot directly from their tops as is often depicted in the movies. It's common for magma to erupt from vents formed on the volcano's side or even travel sideways, forcing its way through underlying rock before finally breaching the Earth's surface.

As vents can open anywhere on a volcano's flank, or even on the rim of its caldera – the cauldron-like hollow filled with bubbling magma – predicting exactly where and when an eruption will occur is incredibly difficult.

Now, researchers at the GFZ German Research Centre for Geosciences in Potsdam have developed a multi-disciplinary method based on physical and statistical analysis that has improved upon the accuracy of current methods.

"Volcanologists often assume that the volcano will behave like it did in the past," said lead researcher Dr Eleonora Rivalta. "The problem is that often only a few tens of vents are visible on the volcano surface as major eruptive episodes tend to cover or obliterate past eruptive patterns. Hence, as mathematically sophisticated as the procedure can be, sparse data lead to coarse maps with large uncertainties. Moreover, the dynamics of a volcano may change with time, so that vent locations will shift."

The team tackled these problems by producing a complex computer model based on the most up-to-date physical understanding of magma behaviour, its likely path of least resistance, and statistical data gathered from previous eruptions. They applied the model to historical data gathered from Campi Flegrei, a caldera close to Naples, Italy, and were able to correctly forecast the location of historical vents that were not used to tune the model.

"The most difficult part was to formulate the method in a way that works for all volcanoes and not just one – to generalise it," said Rivalta. "We will now perform more tests. If our method works well on other volcanoes too, it may help [with] planning land usage in volcanic areas and forecasting the location of future eruptions with a higher certainty than previously possible."

FAST-FOOD TEMPTATIONS ON COMMUTE MAKE YOU FATTER

Walking past a smorgasbord of fast food outlets along your commute could make you fatter, according to research by Arizona State University. The study analysed data from 710 female elementary school employees in New Orleans. Commuters who passed within a kilometre of more supermarkets, grocers and restaurants offering fast food had higher BMIs than those passing by restaurants that offered slower, more formal table service. "The availability and variety of fast-food restaurants along our commute create endless opportunities for a quick, cheap, and unhealthy meal," said Prof Adriana Dornelles, who carried out the research.

In numbers

7p

The weekly cost per household of taxing plastic packaging with less than 30 per cent recycled material, as calculated by a team at Imperial College.

SIX MONTHS

The age at which babies begin showing empathy for victims of bullying, as discovered by a study at the University of the Negev, Israel.

110

The percentage that butterfly numbers are up in England, compared to 2017.

MARINE BIOLOGY

Sharks' fluorescence may protect them from infection

Scientists have deciphered how fluorescent sharks light up in the ocean depths. While researchers have known for a while that invertebrates such as corals and jellyfish can fluoresce thanks to special proteins in their bodies, they haven't figured out exactly how sharks can do it – until now.

> **"Sharks hold so many mysteries and superpowers"**

Scientists from City University of New York and Yale University studied two species of sharks – swell sharks and chain catsharks. Both of these species can live at depths of greater than 450 metres, where they are known to glow with a green colour. The team took samples of chemicals from the sharks' skin, and found that the lighter-coloured areas of skin contained a new type of fluorescent molecule previously unknown to science.

As well as allowing the sharks to glow and therefore recognise each other in the ocean, the fluorescent molecule may even help to protect the animals against infections, thanks to its antimicrobial properties.

"Studying biofluorescence in the ocean is like a constantly evolving mystery novel, with new clues being provided as we move the research forward," said study co-author Prof David Gruber. "After we first reported that swell sharks were biofluorescent, my collaborators and I decided to dive deeper into this topic. We wanted to learn more about what their biofluorescence might mean to them."

There has been a huge surge of interest in studying fluorescent animals, as if we can harness their abilities then it could help us develop new imaging systems for use in science and medicine.

"Sharks are wonderful animals that have been around for over 400 million years. Sharks continually fascinate humans, and they hold so many mysteries and superpowers," Gruber said. "This study highlights yet another mystery of sharks, and it is my hope that this inspires us to learn more about their secrets and work to better protect them."

Swell sharks spend a lot of time resting on the bacteria-laden sea bed, and scientists think that fluorescent molecules in their skin may protect them from infection

In certain memory tasks, chimps perform similarly to human children

ZOOLOGY

Chimpanzees' memories may work a lot like ours

Scientists have previously established that chimps have excellent long-term memories to help them remember the best places to find food. Now, though, they wanted to explore how the apes' working memories performed.

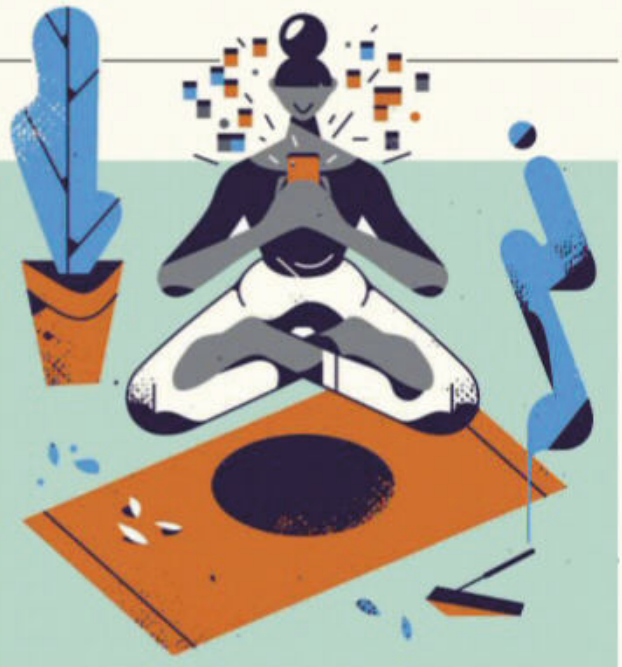
Working memory – sometimes compared to a mental sketchpad – is essential. It allows us to hold new information in our heads and not lose track of what we're doing. For example, remembering the beginning of this sentence as you reach the end of it. To test the chimpanzees' working memories, scientists from the University of St Andrews, the Max Planck Institute and the University of Veterinary Medicine Vienna set out a selection of small, opaque containers and hid food inside some of them, while the chimps watched. The apes then pointed out which box held the food, and if they guessed right, they got to eat it. After each choice, the containers were hidden for 15 seconds. To retrieve the maximum amount of food, the chimps needed to remember which boxes they'd already searched, therefore testing their working memories.

The team made the activity steadily more difficult by adding more containers and by moving them around between searches. The chimps that performed best remembered four food items, but one young animal managed more than seven.

The scientists further tested the chimps by getting them to carry out a similar activity at the same time. Just like humans, the apes performed worse when they were forced to multitask.

"Our findings suggest that chimpanzees perform similar to seven-year-old children in an intuitive working memory task that does not rely on extensive training," says Christoph Voelter, who led the research.

GETTY IMAGE, ALAMY, DAVID GRUBER/ISCIENCE ILLUSTRATIONS: GABRIEL SILVERA



GAMERS

Playing video games may be the best way to wind down, researchers at University College London have found. People who played a smartphone puzzle game for 15 minutes after work were more relaxed, more energetic, and less stressed than those who were given fidget spinners or mindfulness apps to use.

OPTIMISTS

Being a glass-half-full person may help us to sleep better, a study at the University of Illinois has found. A survey of more than 3,500 people aged 30 to 50 found that those who rated themselves as optimistic were 78 per cent more likely to report good sleep.

Good month

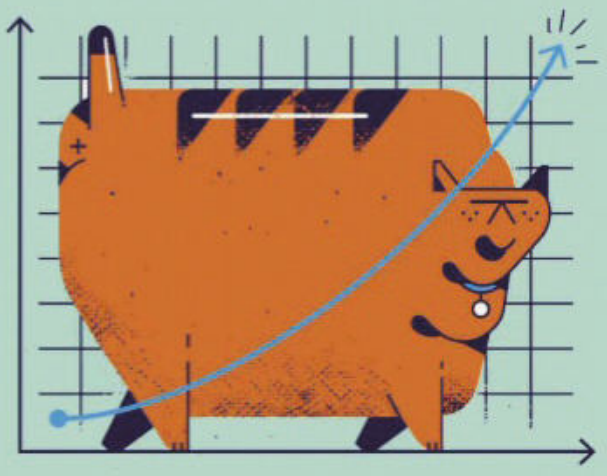
Bad month

FREQUENT FLYERS

Planning a flight? Make sure you're buckled up tight! Changes in the jet stream thanks to climate change are leading to more turbulence. Researchers at Reading University estimate that severe turbulence could rise threefold in the next 50 years.

FAT CATS

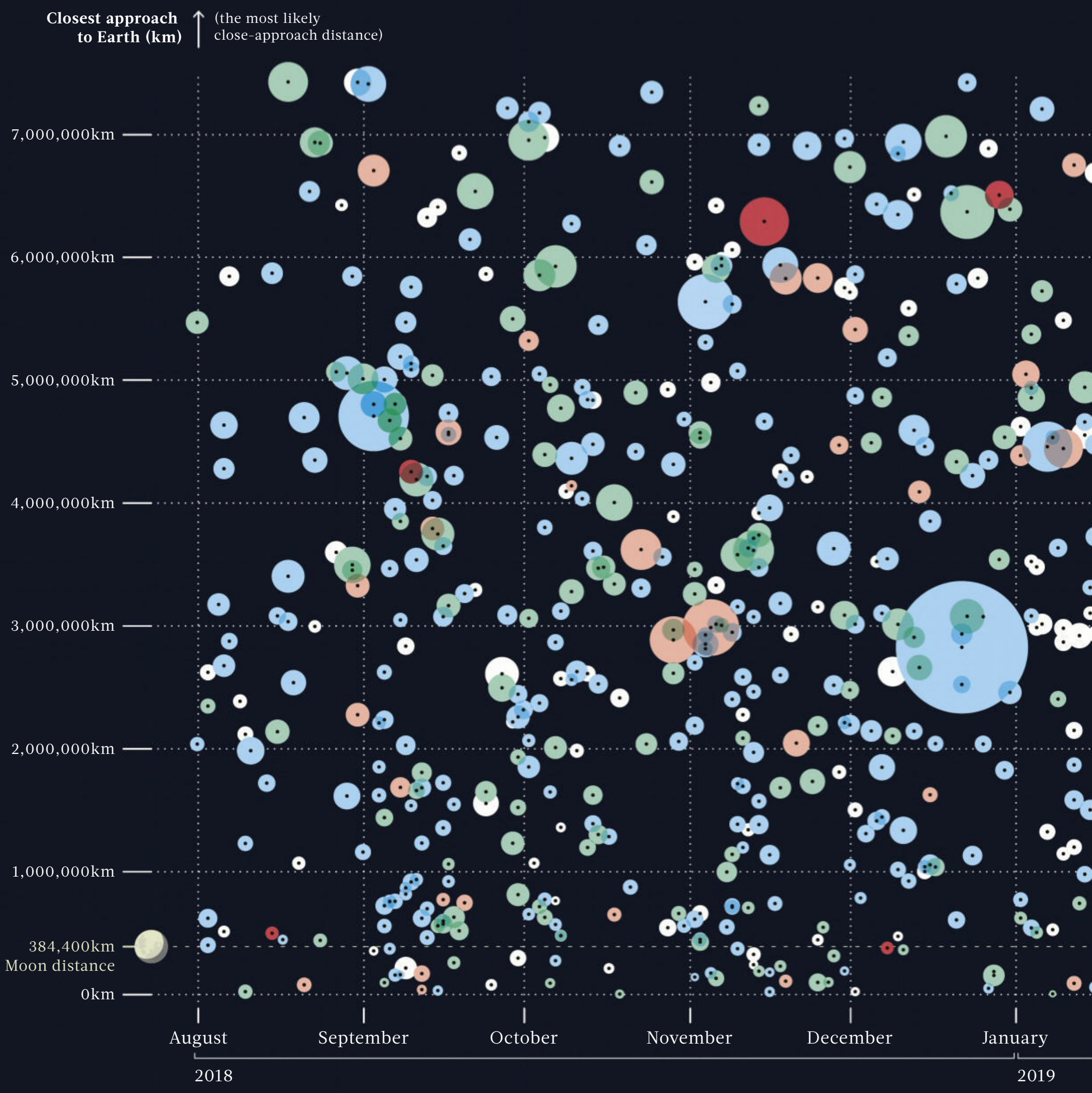
We're not the only ones that are prone to middle aged spread. Researchers in Toronto have found that pet cats pile on the pounds as they age, peaking at eight years old. They suggest that cat owners regularly pop their moggies on the scales to make sure they are a healthy weight.



Data crunch

CLOSE CALLS

On 25 July, an asteroid dubbed 2019 OK passed within 72,000km of the Earth – that's much closer to us than the Moon. It was one of the closest asteroid flybys ever recorded but was only identified as such just hours before hurtling past. NASA tracks all near-Earth objects (NEOs) that are larger than 1km across and has mapped more than 90 per cent of them. This graphic shows all of the NEOs that have passed our planet in the last 12 months.



Distance from Earth

Each circle is a near-Earth object

Size to scale = estimated diameter

= 50m

Colour = velocity (km/h)

(object velocity relative to Earth)

- 3,600-21,600
- 21,601-43,200
- 43,201-64,800
- 64,801-86,400
- 86,401-108,000
- 108,000-129,600

DATA VISUALISATION: FEDERICA FRAGAPANE

2019 OK

February March April May June July August

Time

VAPING CAN DAMAGE BLOOD VESSELS

Smoking an e-cigarette just once could harm blood vessels, even if it doesn't contain nicotine, a study at the University of Pennsylvania has found. In a preliminary study, 31 participants took 16 three-second puffs of a vape containing ingredients common in e-liquids, as well as tobacco flavouring. MRI scans taken before and after revealed a 17.5 per cent reduction in blood flow indicating damage to the lining of blood vessels.

MICROPLASTICS FOUND IN RAINWATER FALLING ON THE ROCKY MOUNTAINS

Samples of rainwater collected in Colorado have been found to contain traces of plastic fibres, researchers at the US Geological Survey have found. Tiny fragments can break off from practically anything made of plastic, which then get washed into rivers and lakes, entering the water cycle and falling as water droplets when it rains.

ARCTIC COULD SOON BE ICELESS EVERY SEPTEMBER

If global temperatures rise by as little 1.5°C, sea ice in the Arctic could completely disappear through September each summer, a study at the University of Cincinnati has found. Computer-based climate models predicted a 6 per cent probability of the sea ice disappearing after a 1.5°C rise, but if the planet warms by 2°C, the likelihood climbs to 28 per cent.

RENEWABLE ENERGY

Europe has enough untapped windfarm capacity to meet global energy needs

The installation of more than 10 million additional wind turbines could help power the planet for the next three decades

An analysis of all suitable sites for onshore wind farms across mainland Europe suggests that the continent has the potential to supply enough energy for the whole world until 2050.

The study, carried out by researchers based at the University of Sussex and Denmark's Aarhus University claims that installing 11 million wind turbines over five million square kilometres of Europe could generate 497 exajoules of energy: enough to comfortably meet the expected global energy demand in 2050. Turkey, Russia and Norway have the greatest potential for future wind power, the researcher say.

"Our study suggests that the horizon is bright for the onshore wind sector and that European aspirations for a 100 per cent renewable energy grid are within our collective grasp technologically," said co-author Benjamin Sovacool, professor of energy policy at the University of Sussex. "Obviously, we are not saying that we should install turbines in all the identified sites but the study does show the huge wind power potential right across Europe which needs to be harnessed if we're to avert a climate catastrophe."

By analysing data from detailed global wind atlases, the team was able to rule out regions that were unsuitable due to the proximity of houses or roads, or restricted due to military or political reasons. Overall, they determined that around 46 per cent of Europe's territory would be suitable locations for onshore wind farms.

"Critics will no doubt argue that the naturally intermittent supply of wind makes onshore wind energy unsuitable to meet the global demand," said Peter Enevoldsen, assistant professor in the Center for Energy Technologies at Aarhus University. "But even without accounting for developments in wind turbine technology in the upcoming decades, onshore wind power is the cheapest mature source of renewable energy, and utilising the different wind regions in Europe is the key to meet the demand for a 100 per cent renewable and fully decarbonised energy system."

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YEMEN EMERGENCY

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GENDER-NEUTRAL PRONOUNS REDUCE MALE BIAS

Using gender-neutral pronouns instead of gender-specific ones such as 'he' or 'she' can promote equality, research suggests. More than 3,000 people took part in a survey in Sweden, where a gender-neutral pronoun ('hen') was adopted in 2015. Participants who were asked to use gender-neutral pronouns to describe a cartoon of a non-gendered figure were subsequently less likely to give a male name to a second fictional character than participants who were asked to use masculine pronouns, suggesting a reduction in mental bias towards males. The researchers also found that those who used gender-neutral pronouns expressed more positive and tolerant attitudes towards women and LGBT individuals.

DEMENTIA

Staying sociable could help keep dementia at bay

There are currently around 850,000 people living with dementia in the UK, with estimates by the Alzheimer's Society indicating this could soar to more than two million by 2051. There is currently no cure, but maintaining social links throughout middle age could help to lower the risks of developing the disease, a study at University College London suggests.

The team analysed data collected between 1985 and 2013 about people's frequency of contact with friends and relatives. They then checked the electronic health records of the same people up until 2017 to see if they'd ever received a dementia diagnosis.

They found that those who saw friends and relatives almost daily at the age of 60 were around 12 per cent less likely to develop dementia than someone who only saw one or two friends every few months.

They found a similar but less strong effect in the degree of social contact in those aged 50 and 70 and subsequent dementia.

"People who are socially engaged are exercising cognitive skills such as memory and language, which may help them to develop cognitive reserve – while it may not stop their brains from changing, cognitive reserve could help people cope better with the effects of age and delay any symptoms of dementia," said Prof Gill Livingston, who took part in the study. "Spending more time with friends could also be good for mental wellbeing, and may correlate with being physically active, both of which can also reduce the risk of developing dementia."

1 IN 6

The number of people over the age of 80 in the UK who have dementia.

62%

The percentage of dementia sufferers who have Alzheimer's, making it the most common form of dementia.

Dementia is one of the main causes of disability later in life, ahead of cancer, cardiovascular disease and stroke.

Think you've got regeneration skills, Wolverine? Get a load of this freshwater hydra...

ZOOLOGY

Secret of the 'immortal' hydra's regeneration ability uncovered

This relative of jellyfish can regrow its entire body from a small piece of tissue

Who wants to live forever? A tiny freshwater creature called the hydra does (and can!), and scientists at the University of California have revealed the source of its remarkable healing ability.

The hydra belongs to the same phylum as jellyfish and corals. It is named after the serpent monster from Greek myth, which regrows two heads each time one is cut off. But freshwater hydras have an even more impressive ability than the mythical beast: an entire hydra can regrow from a small piece of tissue in only a few days. Biologists are particularly excited by this ability, since many of the networks involved in the healing process developed early in the process of evolution, meaning that they are shared among many animals, including humans.

"In other organisms, like humans, once our brain is injured, we have difficulty recovering because the brain lacks the kind of regenerative abilities we see in hydra," said researcher Abby Primack. Therefore, if hydra's healing ability can be fully understood, it could potentially be harnessed to heal brain injuries or degenerative disease.

When a hydra is damaged, it grows new tissue from stem cells. Stem cells are found in human embryos and adult bone marrow. They are a basic form of cell which can do something no other type of animal cell can do: they can reproduce to create a different type of cell with a specific function, such as brain cells or skin cells.

The team analysed molecules known as RNA to study the processes that turned hydra stem cells into different specialised cells. RNA, or ribonucleic acid, is the molecule that reads DNA and carries out its instructions. By studying the RNA, they could deduce which particular genes were being activated in the process.

"The beauty of single-cell sequencing and why this is such a big deal for developmental biologists is that we can actually capture the genes that are expressed as cells differentiate from stem cells into their different cell types," said Celina Juliano, who took part in the research.

Hydra has not just one type of stem cell, but three. The researchers tracked how each type of stem cell could develop into different cell types. They learnt that one path branched out to create either neurons or gland cells, as though the cell hadn't made a decision when the process began. In future studies, the team wants to understand what genes determine this decision.

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Prof Oliver Hardt neuroscientist

Horizons

What if I could remember everything?

Far from being a flaw, the ability to forget may play a crucial role in the brain's memory system

YOUR WORK FOCUSES ON FORGETTING...

The majority of the public, and also many of my colleagues, think of forgetting from the perspective of memory failure. Forgetting is thus considered to be a glitch of memory. It is a relatively recent view in my field that forgetting could be a fundamental function of the memory system, something that it needs to function properly. On one hand there is a system that constantly makes sure that structures that have been formed during memory formation are maintained, and, at the same time, there's a process that tries to eliminate these structures. We now refer to this process as an 'active forgetting mechanism', a process that brains use to remove memories with the goal to keep memory optimally functional.

SO FORGETTING IS A GOOD THING?

I think there is indeed a bliss in forgetting. Most of what you experience you can really forget. It improves the adaptive aspect of the memory system in the sense that the brain really only retains what is considered useful for the major tasks at hand, to improve chances of survival. If, for example, you experience a situation that allows for 20 possible reactions based on a comprehensive and unselective catalogue of past events, but actually only two were effective, you have a high chance of selecting a wrong course of action. But if the memory system is designed to make sure you only retain the best responses, then perhaps you only have to select from four choices, and the chance of you doing the right thing is much higher.

HOW DOES THE BRAIN DECIDE WHICH MEMORIES TO REMEMBER AND WHICH TO FORGET?

That is a big question now for our field. If there is this built-in process of forgetting, why do we retain some memories? The thing is, organised forgetting is necessary because we tend to remember too much. That's the basic problem. We proposed that the brain is a promiscuous coding device, that it just encodes whatever it can when things happen, because the brain usually has a hard time figuring out what is important and what is not when things unfold. It is really hard to make that call because things happen too fast, often they only happen once, and you cannot readily make the decision, "let's keep that for later because I might need to remember it in the future".

The best approach may be to try to remember as much as possible when things happen and sort it out later. We therefore believe certain forms of forgetting occur predominantly during sleep, counteracting the effects of unselective, 'promiscuous', memory formation. But my view is that there are many other active forgetting processes. They operate on different timescales along the lifetime of a memory.

IS THERE AN INBUILT HIERARCHY OF REMEMBERING AND FORGETTING?

There are ways to decide what might be important in the future and thus should be kept instead of being erased. For example,

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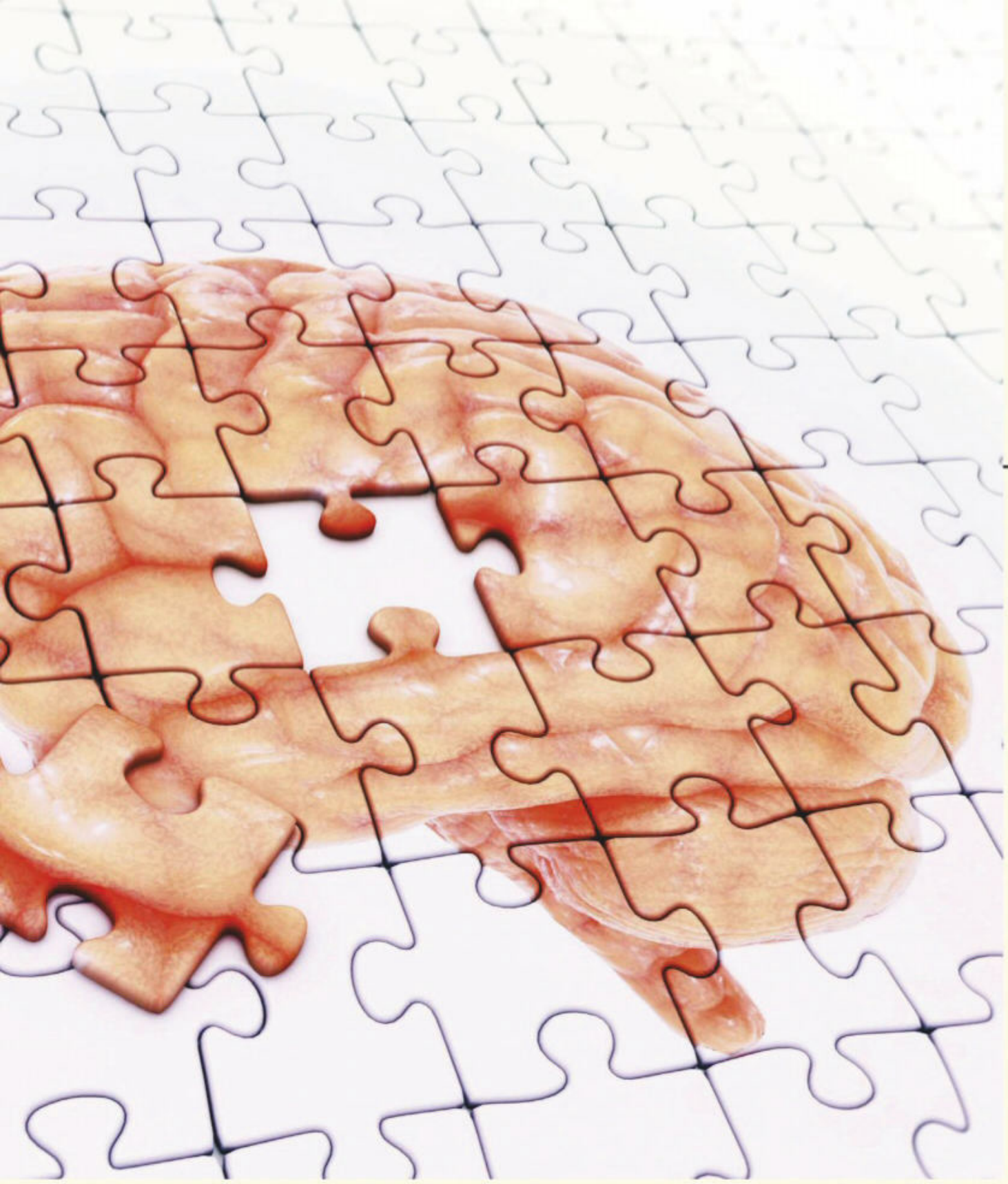
"The brain really only retains what is considered useful for the major tasks at hand, to improve chances of survival"



something that is new, that we have not seen before in this way, has a high chance of being retained. This is because novelty triggers systems that release substances like dopamine, which increase the lifetime of memories formed during this time. Each surprise is a novelty because based on our existing knowledge and memories we did not predict it. And these kind of emotional reactions like surprise, fear, happiness and so forth, trigger the release of substances and certain other processes that somehow strengthen the connections between neurons, resulting in longer-lasting memories. In other words, these memories last longer because they are more resistant to active forgetting processes.

Another way how memories have a higher chance of survival is repetition. I think that this is especially a feature of humans. We talk a lot, and we live in groups. For 30,000 years now we have been sitting around the proverbial fire at night, talking to our kin or loved ones about what happened during the day when we get back home from hunting and foraging, or the office nowadays. What we experienced we explain to other people, and they ask us probing questions during this reporting, things that interest them particularly. This kind of guided repetition is another way of filtering out what is important and what can be forgotten. We usually only talk with people about what we find important and interesting, but when others start to ask us targeted questions to tickle out more information about a certain event, it is a way of making sure that the knowledge of everybody is used to extract the most relevant aspects from your experience and commit this to the memory of many.

This repetition and sharing strengthens the memories of the narrator and distributes it across the brains of the listeners, making the acquired knowledge resistant against the brain's forces of forgetting by way of strengthening and distribution. But the question of how, on the biological level, repetition, surprise or other emotional reactions protect against forgetting has not been fully answered. The way my group is looking at this currently is trying to understand how these ways of making memories stronger affect the systems that convey the message 'forget' in the brain.

IS IT POSSIBLE THAT THE FORGETTING MECHANISM GOES HAYWIRE IN SOMEBODY WHO SUFFERS FROM A DISEASE SUCH AS DEMENTIA?

That is a hypothesis I have been proposing for a couple of years now. If there is a hardwired forgetting process in the brain, then, like any other processes of the brain, it can get dysregulated, and this dysregulation could promote diseases of forgetting. I have suggested that Alzheimer's disease might not start as a problem of making memories, but as excessive forgetting. Thus, to approach this disease, it may be helpful to try to tone down an overactive forgetting process. One group has done just that. They used the approach that we used to stop normal forgetting in a healthy rat, and used it in a transgenic [genetically altered] rat that expresses some symptoms of Alzheimer's disease, such as the famous plaques [fragments of protein that clump together and interfere with signals from neurons]. They found that blocking the forgetting process reduced the plaques and normalised memory retention in this transgenic rat. Thus, I think it is at least a plausible alternative hypothesis that excessive memory loss in certain neuro-degenerative conditions can result from the overactive and dysregulated forgetting process we have discovered.

PROF OLIVER HARDT
Oliver is assistant professor in the Department of Psychology at Canada's McGill University.
Interviewed by* BBC Science Focus *commissioning editor Jason Goodyer.

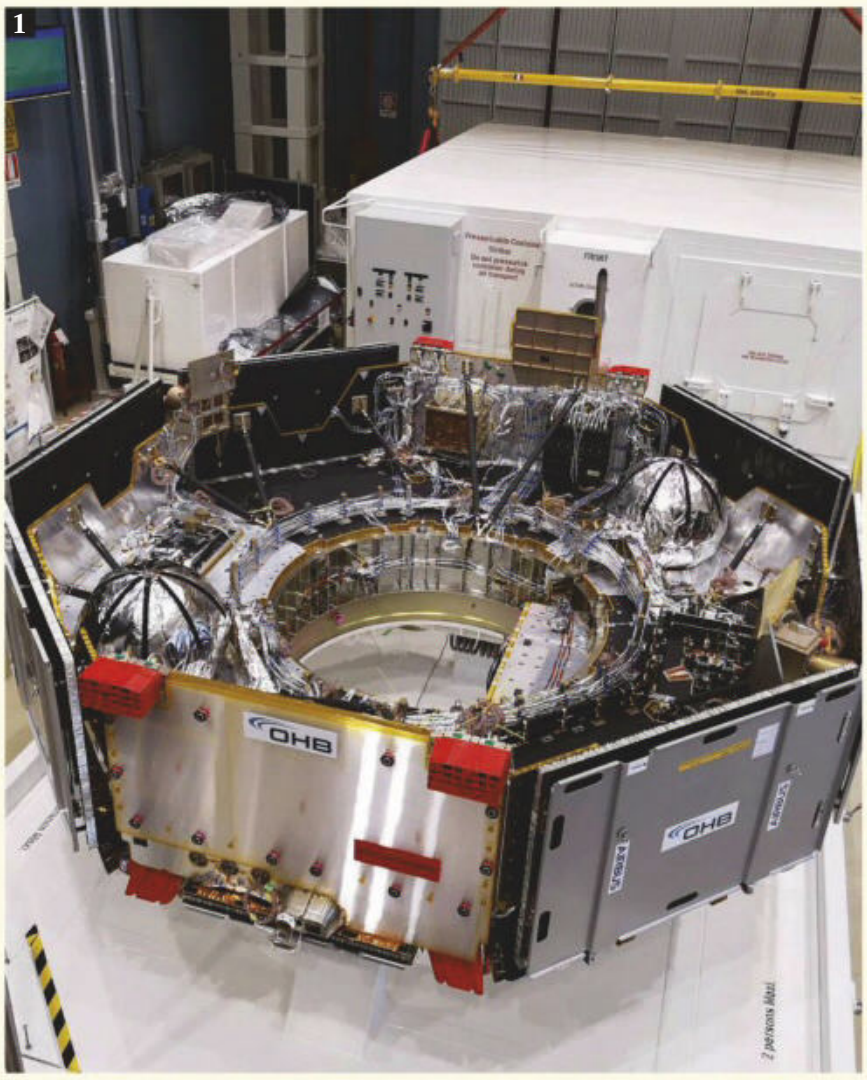
Turin, Italy

SPACE

ESA's Martian rover readies for launch

If all goes to plan, the European Space Agency's Rosalind Franklin rover, currently being tested in Turin, Italy, will be the first to search for life on the Red Planet

2



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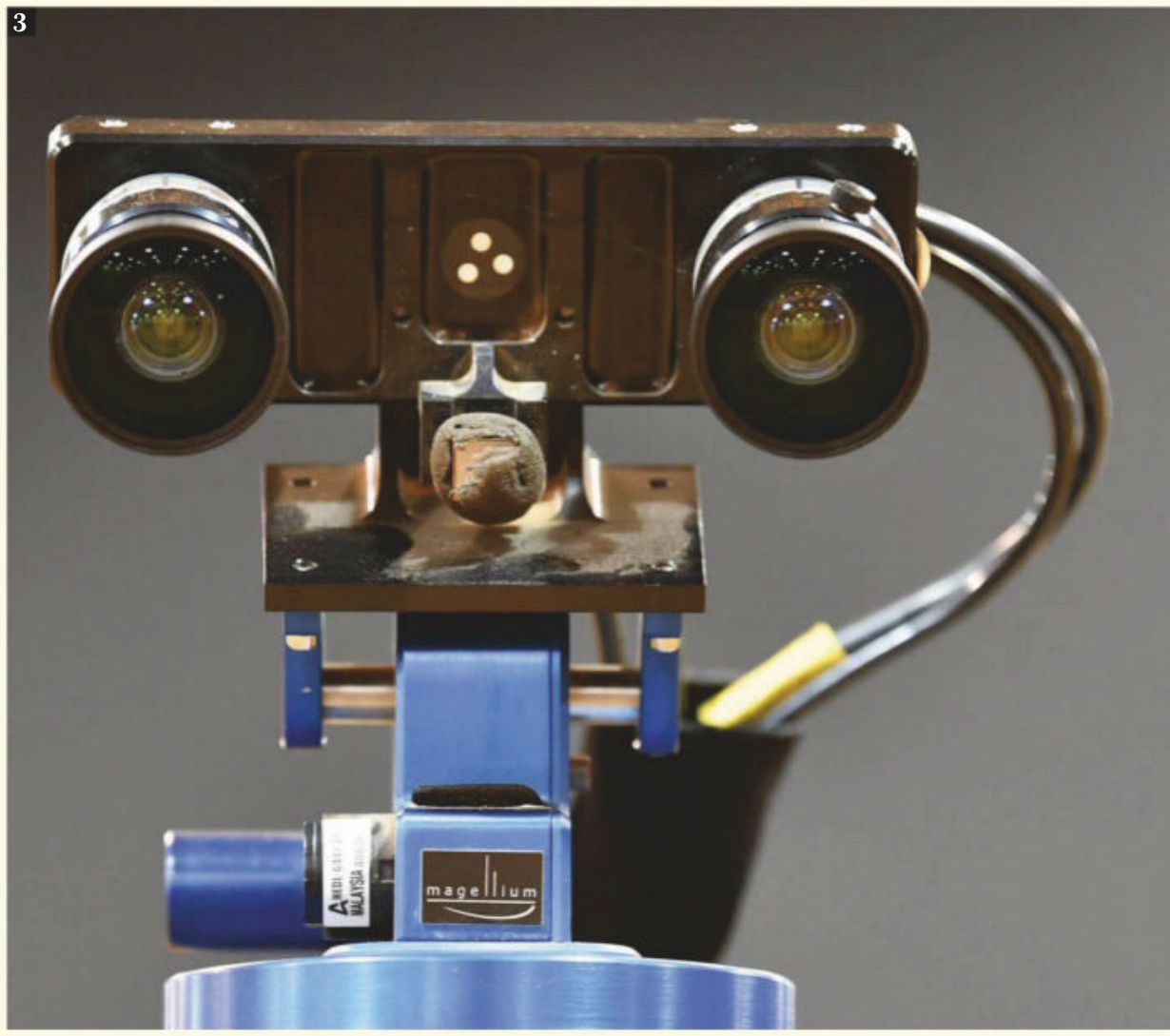

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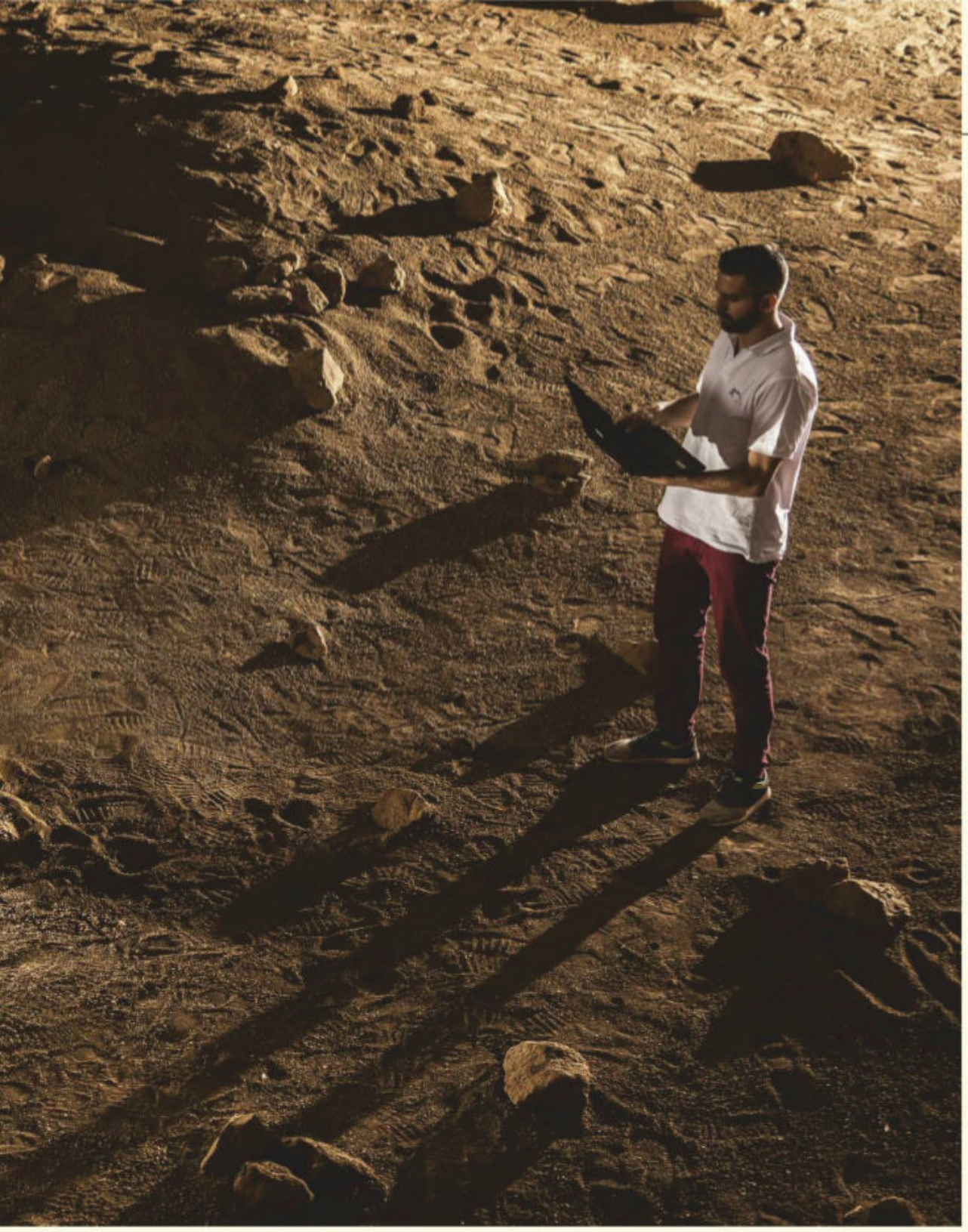

1. The ESA carrier module that will house the Rosalind Franklin rover on its journey from Earth to Mars is under construction here. It will also provide the communication link between Earth and the spacecraft during the trip.

2. The Aerospace Logistics Technology Engineering Company (ALTEC) in Turin houses a Mars yard filled with 140 tonnes of rocks and soil, specially designed to mimic the surface of the Red Planet. This allows scientists to rehearse various scenarios prior to launch.

3. The two cameras mounted on top of the Rosalind Franklin rover allow it to 'see' in 3D. It will use the cameras to analyse the slopes and the rocks ahead of it to make sure it doesn't get stuck.

4. ALTEC has a platform with a well that will allow the rover operators to test the rover's drilling equipment. The rover will drill two metres down into the Martian surface to sample the soil, analyse its composition and search for evidence of past – and perhaps even present – life buried underground.

5. All of the components of the rover are sterilised before they are assembled in a purpose-built clean room. This ensures that dirt or microbes from Earth will not contaminate any evidence of life on Mars.

6. The rover is scheduled for launch in July 2020. It will then embark on an eight-month interplanetary cruise before landing on the surface of the Red Planet.

ESA X4, GETTY IMAGES

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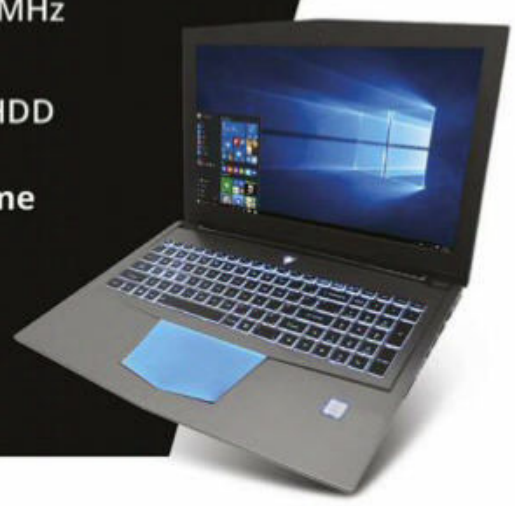

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

ANALYSIS

PET CATS: SHOULD THEY BE KEPT INDOORS?

Climate change, habitat loss and car accidents are among the human-made threats to wildlife populations. But research suggests that pet cats could also be contributing millions to the small animal death toll...

“There are plenty of surveys that show cats are killing things. But the long-term effects of that have been difficult to find”

Yes, cats kill wildlife. If that bothers you, perhaps consider keeping Tiddles indoors

One in four adults in the UK owns a cat, according to the UK’s leading vet charity. That adds up to 11.1 million cats, many of whom free-roam over great distances. With so many felines prowling the country and with British wildlife in a precarious state, it begs the question, how harmful are domestic cats to the species they prey on?

The Mammal Society, a charitable organisation concerned with the welfare and conservation of mammals, surveyed cat owners to find out just that. Over the course of five months, on average a single cat brought home 11 prey items, which included all manner of animals from house sparrows to grass snakes. This may not seem like much, but with millions of cats in Britain, this could mean that some 274 million dead animals are dropped on owners’ doorsteps each year.

In the face of such startling figures, what is a responsible cat lover to do? There’s one obvious answer: keep these cuddly killers indoors, permanently.

But the solution isn’t quite that straightforward, says Dr John Bradshaw, who has studied domestic cats since the mid-1980s. “In this country, the evidence that cats are causing any serious depletion in wildlife populations is pretty flimsy,” he explains. “That’s not to say they aren’t killing things. There are plenty of surveys that show they are. But the long-term effects of that have been difficult to find.”

Most species targeted by domestic cats will have lots of offspring, to counter the expectation that many will die before they reach adulthood.

“Cats aren’t very efficient hunters,” adds Bradshaw. Their prey is most likely already in a poor condition, dead or dying, when they catch it. “Really, focusing on the cat is counterproductive.”

To demonise cats, Bradshaw suggests, would distract from the real dangers to wildlife in the UK: loss of habitats, reduced availability of food and the increased use of pesticides and fertilisers. These threats were identified in the UK’s State of Nature report in 2016, which brought together data from more than 50 different organisations. Though Mittens may not be public enemy number one on our shores, elsewhere in the world cats aren’t off the hook.

In 2013 an American review found that pet cats allowed to roam free could be linked to the death of 684 million birds in the US each year. This was three times the figure for birds killed by cars and 12 times as many as killed by wind turbines.

Scott Loss, one of the authors of the study, wants to make one thing clear: “It’s not an issue relating to the cats themselves. It’s a human issue. The key is getting people to realise the negative impacts that free-roaming cats have, and adjusting their behaviours regarding cat ownership. We’re not blaming cats.”

For owners worried about wildlife, Loss recommends keeping their pet cats indoors. Or, if they’re outdoors, to have them restrained in some way, either by installing ‘catios’ – outdoor cat enclosures that enable them to run around but separate them from wildlife – or even walking them on a lead. “Often, those suggestions don’t go over well with cat owners. They say ‘my cat isn’t a problem’ so they don’t think it’s worth restraining them.” says Loss. If you don’t have the space for a ‘catio’ and can’t imagine your ➤

GETTY IMAGES X 2

furry friend happily taking to a leash, then Bradshaw has some advice.

First off, to dissuade your cat from the hunt, check their food bowl. "The first thing to look at is their cat food. Is your cat getting all the nutrition it needs? If not, then you're almost giving it an excuse to go hunting." Bradshaw explains. Otherwise if you want a pet cat, but can't put up with its murderous tendencies, Bradshaw suggests getting a kitten who has never been out, or a cat that's always been kept indoors. Bringing a cat inside who has previously explored the Great Outdoors can have its challenges, and their individual personalities will determine how well they'll adapt to life in captivity.

Is there anything then that owners can do to keep Tiddles happy and healthy during the transition from the great outdoors to the living room? Dr Lynn Bahr, a feline vet in the United States, creates products and toys that enrich the lives of indoor cats. Bahr says that giving cats an opportunity to play is essential. "Keeping them active, exercised mentally and physically is extremely important," Bahr stresses. "I hide toys and treats around the house for my cats, so they have to go and forage for them as they would do in the wild." Though she warns that life on the inside poses a range of health risks for cats: obesity, diabetes, depression, to name just a few. That isn't to say there aren't dangers outdoors – car accidents, cat fights, feline HIV, ticks and fleas all threaten to end a pet's life prematurely.

For those concerned about their pet's happiness and the state of nature, Bradshaw suggests looking into the wildlife in the area and finding out if there are vulnerable or endangered species nearby. If there are, restrict your cat's outdoor activity. "But making habitats for wildlife – feeding birds, building log piles at the bottom of your garden for mice – is actually much better for nature than locking your cat away."

by **AMY BARRETT**

Amy is editorial assistant at BBC Science Focus. *She has a BA in publishing with creative writing.*

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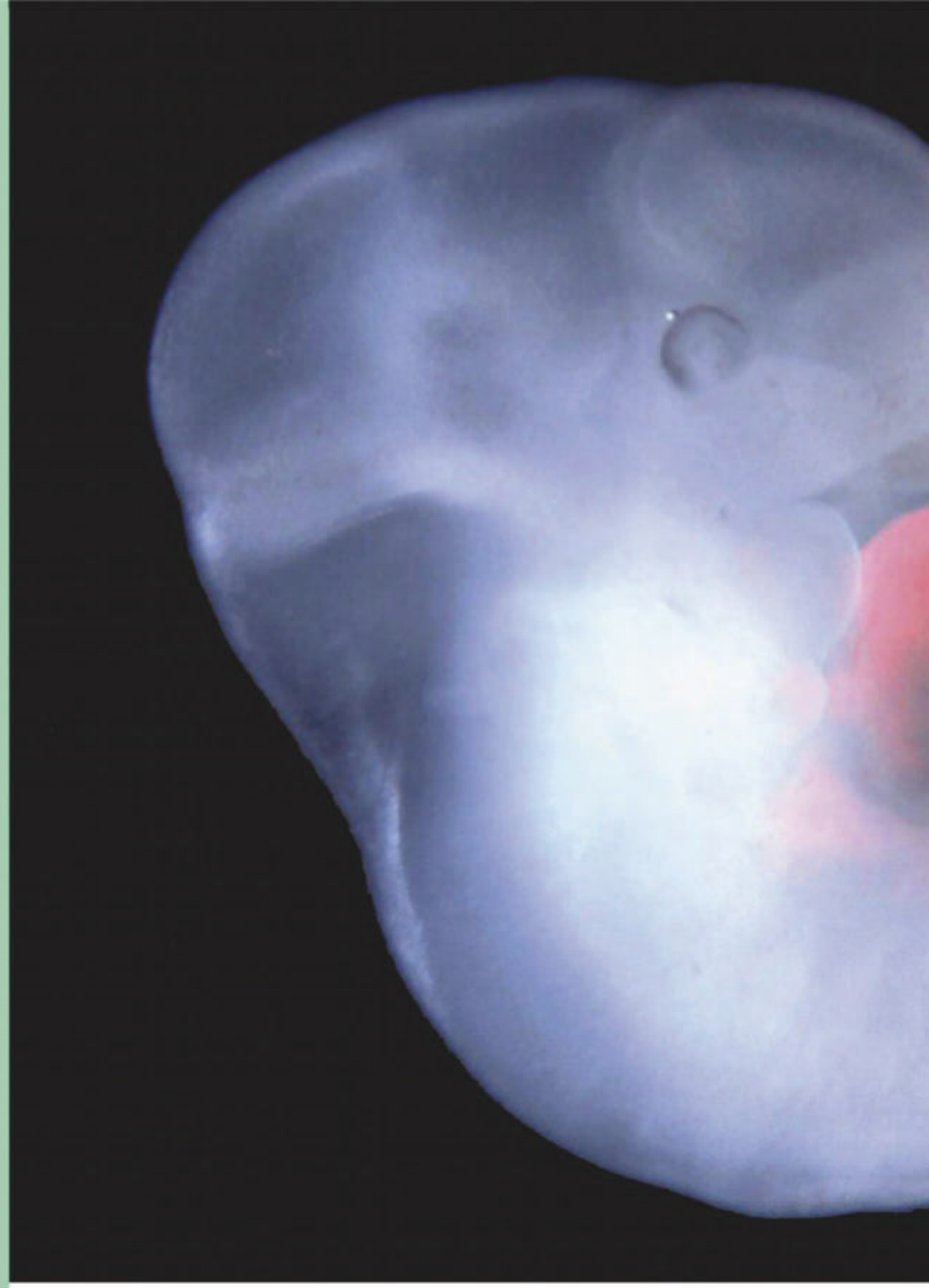


REVIEW

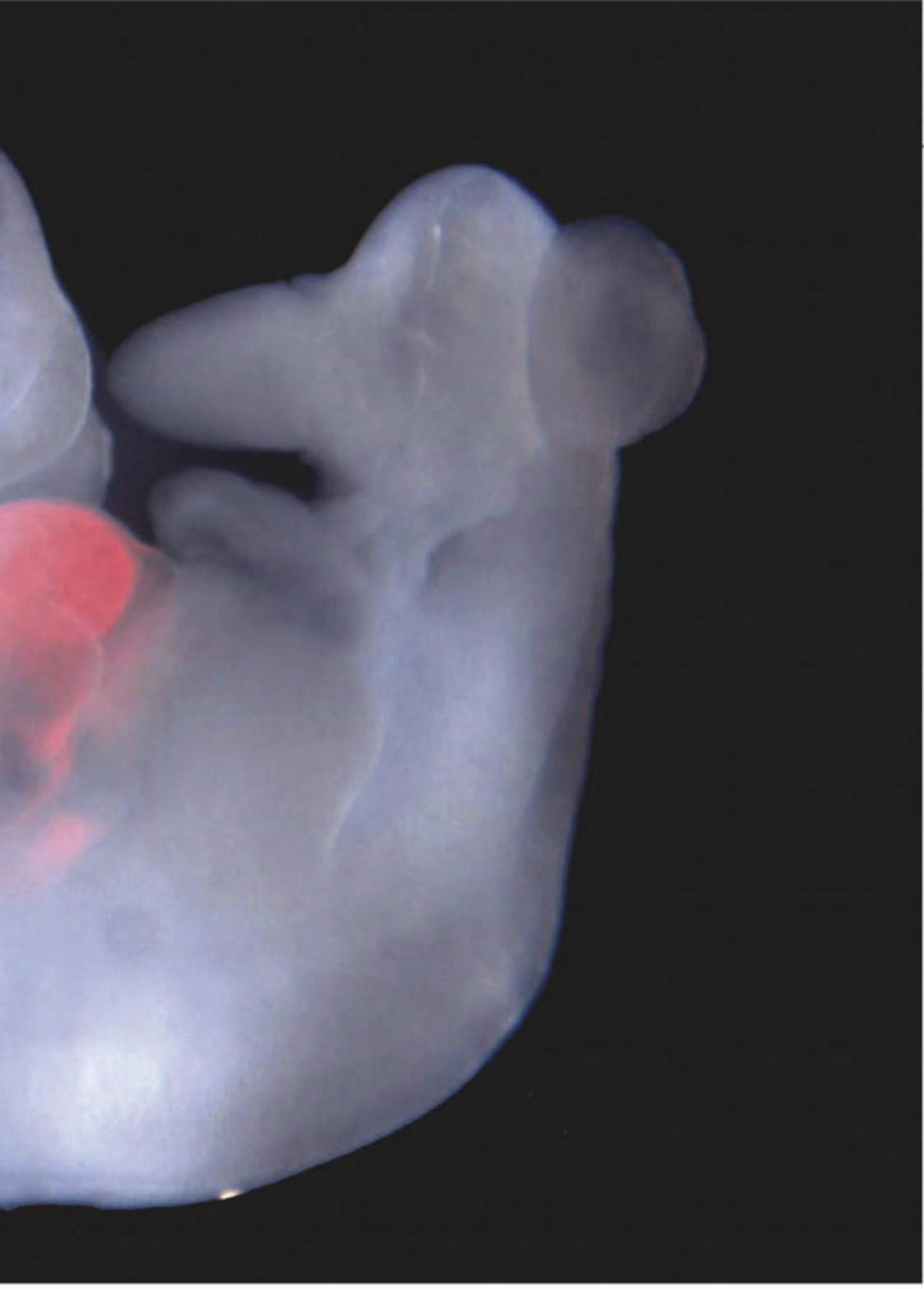
HUMAN-ANIMAL HYBRIDS: CAN WE JUSTIFY THE EXPERIMENTS?

Human-animal 'chimeras' could save lives, but is it right to use them for their organs?

What are the experiments?

Human-animal hybrids, also known as 'chimeras', are creatures with a mixture of human and animal cells. They are created by injecting human stem cells into the embryo of another animal. So far, no human-animal hybrids embryos have been brought to term ('term' means full gestational period).

But now, biologist Dr Hiromitsu Nakauchi at the University of Tokyo plans to bring mouse-human



LEFT: Cells derived from rat stem cells developing in the heart of a mouse embryo

BELOW: Prof Juan Carlos Izpisúa Belmonte has been carrying out chimera experiments in China

SALK INSTITUTE

and rat-human hybrids to term following a change in Japanese regulation in March 2019. Pending approval of the Japanese government, the embryos no longer have to be destroyed after 14 days of development. Nakauchi's hybrids will be brought nearly to term in surrogate animals, with mouse embryos developing for 14.5 days and rats for 15.5; full-term is around 19 to 21 days for mice, and 21 to 26 days for rats.

Similarly, the Spanish newspaper *El País* reported in July that a team from the Salk Institute in California had created human-monkey hybrid embryos. The team, led by Prof Juan Carlos Izpisúa Belmonte, carried out the experiments in China, most likely since the National Institute of Health in the USA has placed a moratorium on funding human-animal hybrid research. The research hasn't yet been published, so there are few details about the work, but the embryos were most likely terminated within 14 days.

"Human-animal hybrid experiments are working towards the same goal: using animals to grow tailored organs ready for transplant, with a low risk of rejection"

What is the goal of the experiments, and why create hybrids in the first place?

Last year, more than 400 people in the UK died waiting for an organ transplant, and over 6,000 are still waiting. Rather than relying on donated organs, there are several projects working on manufacturing replacements, from 3D-printed hearts made of collagen (see p15) to bionic pancreases. Human-animal hybrid experiments are working towards the same goal: using animals to grow tailored organs ready for transplant, with a low risk of rejection. Nakauchi plans to grow a pancreas made of human cells. In previous ▶

experiments, his team successfully created a rat with a pancreas made of mouse cells. The pancreas was later transplanted into a mouse engineered to have diabetes, and the mouse was effectively cured. Any organs that could be used for transplantation in humans would have to be grown in a larger animal, such as a pig or sheep, so that the organ would be big enough for the patient to use. Additionally, the chimeras tend to be more successful if the two species are closely related.

Have human hybrids been created before?

Izpisúa Belmonte's team reported the first successful human-animal chimera in 2017, when they created pig-human hybrid embryos. The researchers modified the human stem cells to fluoresce so that any human cells in the embryo glowed. After developing for three to four weeks, only around 1 in 100,000 cells was human: far too low to be useful, and not localised in any particular organ.

"Chimeras are often met with the criticism that they are 'unnatural' creatures. But is that a valid reason to stop the research?"

What are the ethical concerns?

Chimeras are often met with the criticism that they are 'unnatural' creatures. But is that a valid reason to stop the research? "People think, 'Oh, we shouldn't be playing God, we shouldn't be creating these things that are unnatural,'" explains Dr Mackenzie Graham, a research fellow in neuroethics at the Oxford Uehiro Centre for Practical Ethics. However, he believes this

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concern is misdirected. "To me, the more serious ethical concern is: if we are creating creatures that have a higher moral status because of, say, higher cognitive capacity, they might be entitled to treatment that we're not giving them in a research context."

Moral status is the concept that determines how far a creature's interests should be taken into account. "Basically, how it seems to work is we all agree that adult humans have moral status, so I can't harm you or kill you, and the reason for that is that your interests count," explains Graham. "A tree doesn't have moral status, so it's okay that I chop it down, even though that's not strictly speaking in its interests because it will kill it."

The important question is what gives something higher moral status. "Most philosophers tend to think that what gives us moral status is sophisticated cognitive capacity," Graham says. "Others have a more inclusive view of moral status, and say things like 'Well, if an animal can suffer and feel pain and be harmed, that should count for something.'" In essence, the greater the capacity for suffering something has, the better it deserves to be treated.

So, when creating human-animal hybrids, researchers need to know whether their capacity to suffer has changed. "What if we inject these chimeras with stem cells and, because these stem cells can turn into any other type of cell, what if they make their way up into the brain and make changes to the brain which could result in cognitive improvements to the animal?" Graham suggests. "Now, you have a mouse that is much smarter than a normal mouse. What if this mouse was self-conscious in the way that a human is?"

Izpisúa Belmonte's team have placed safeguards against human stem cells affecting the hybrid's mental capacity. Estrella Núñez, a collaborator on the project, said that the cells had been modified so that if human cells migrate to the brain, they will self-destruct.

That said, even if the hybrid's moral status is raised, it's important to know by how much. "It still seems to me quite unlikely that even mixing human cells with a pig is going to push them up to a level of moral status that would be concerning," says Graham. He believes that using the organs for transplant can be justified since a human's moral status is much higher. "If human lives are at stake, hybrids would need to have basically the same moral status as us in order for it to be unethical to use them for organs, and this seems highly unlikely."

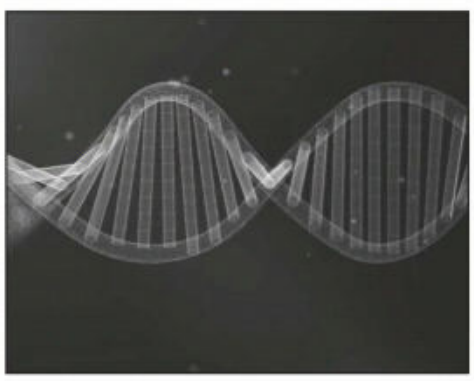
How likely is it to be successful?

Chimeras are most likely to survive if the two species are closely related; the mouse-rat hybrids created by Nakauchi's team survived into adulthood. However, Alejandro De Los Angeles, who carries out similar research at Yale University, believes that humans and monkeys may not be closely related enough. "The evolutionary distance between humans and monkeys spans 30-40 million years, so it is unclear if this is even possible," he told *The Guardian*. "This difference is greater than 10 million years between mice and rats, and even the efficiency of making mouse-rat chimeras is already quite low."

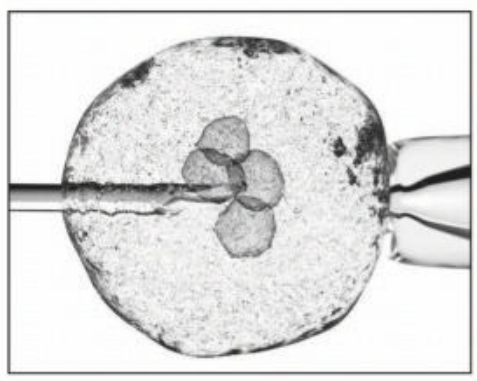
LEFT: In 1967, Louis Washkansky was the first person to receive a human-human heart transplant. The operation was groundbreaking, paving the way for further transplants, but a lack of organs is a serious problem. Chimeras could help surgeons save more lives

by **SARA RIGBY**
Sara is online assistant at BBC Science Focus. *She has an MPhys in mathematical physics.*

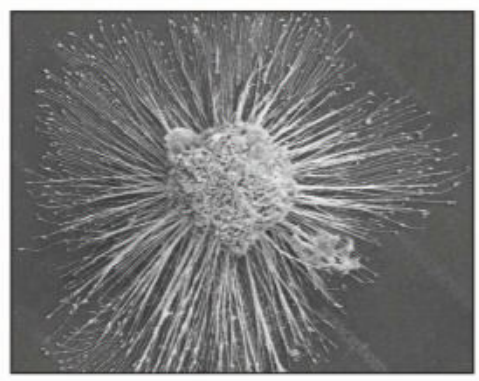
HOW ARE THE TRANSPLANT ORGANS CREATED?



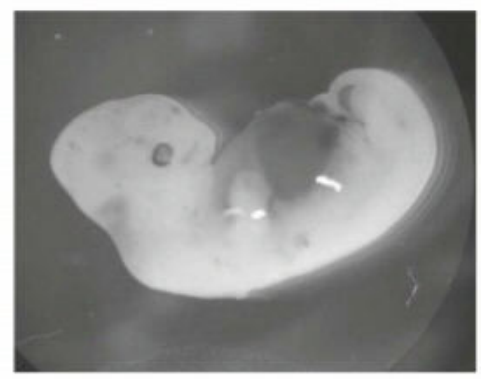
Edit the DNA of an animal embryo to remove the gene for one organ.



Human induced pluripotent stem (iPS) cells are injected from the organ recipient into the embryo. These iPS cells can develop into almost any other cell.



The iPS cells (pictured) fill the gap left by the embryo's genes and build a human organ with the recipient's genes.



The embryo is placed in a surrogate animal and brought to term, and an animal with one human organ is born.

COMMENT

SEAGULLS: ARE THEY GETTING MORE AGGRESSIVE?

They steal your chips and headlines claim they'll eat your pets for pudding. But are these raucous birds really out to get us?

The media tells us that Public Enemy Number 1 is a vicious, white-plumaged menace known as The Seagull. With a hooked bill, beady eyes and a noisy call that rings across the land at any hour of the day or night, it seeks to tear our flesh, steal our food, and given the chance, murder and eat our children and pets.

Herring gulls are rated in the highest category of conservation importance, according to the RSPB

"Seagull terror: lock up your babies", "Giant gulls ate my dog" and "Seagull flew off with cat" are among the many sensational headlines of recent years.

But are gulls really as bad as the tabloids would have it, and are things becoming worse? Are these birds becoming more predatory, aggressive and dangerous? Let's look at the evidence.

There's no doubting that the big gulls of Europe and adjacent regions – the herring gull, lesser and great black-backed gulls in particular – are formidable and potentially dangerous. (There is no such thing as a 'seagull' but it is the common name for a few of the gull species.)

Yes, a gull will snatch food from a hand, especially if held aloft and out of direct human eyeline. And, yes, gulls may strike, peck or bite when defending themselves, their chicks or their nest. Furthermore, their bills or wings may make contact with people when the birds grab food. Such incidents are not uncommon and have even resulted in lacerations to the hand or face, injuries that – in rare cases – have required a short visit to the hospital.

But are such events on the increase? It might seem that they are, but this is mostly a consequence of a faster-paced news cycle and an anti-gull agenda that has emerged within certain sectors of the press. The genuine possibility that such events are on the increase does exist – perhaps because people and gulls are increasingly sharing the same space – but there isn't any reliable scientific indication that they are. Nor is there data showing that gulls are becoming less afraid of people, or more aggressive.

Numerous studies have looked at the diet and feeding behaviour of gulls. Gulls living in and close to cities are adaptable. Their diet is diverse, and includes food scraps and waste such as chicken, bread, fruit and vegetables. Urban gulls frequently visit rubbish dumps, where they scavenge for edible foodstuffs. This could mean that many populations of gulls are becoming more reliant on the spoils of human civilisation.

But the same studies also show that gulls in urban settings will still glean prey from nearby coastal habitats, and – surprisingly – eat numerous items from wasteland, grassland and forest edges, including earthworms, insects and plant parts. In fact gulls consume seeds and fruit so frequently that they're important seed dispersers. All in all, there's no evidence from dietary or ecological studies that gulls are becoming more predatory.

So what about those reports where gulls have supposedly done such things as grab and consume a small dog, as reported in the British press during the summer of 2019? This possibility isn't out of the question. Large gulls can and do capture and consume small rabbits, animals not that different in size from tiny dogs. Again, however, there are no indications that such behaviour is any more common than it ever was.

An implication of gull-themed stories in the popular press is that gull numbers are out of control, and that action is needed. But in fact many gull species aren't increasing, but declining to a worrying degree.

The myth of the rapacious killer seagull, with a skyrocketing urban population that's intent on harming us isn't just scaremongering. It's irresponsible and harmful, given that we're talking about birds that need our tolerance, and perhaps even our help.

by **DR DARREN NAISH** *(@TetZoo)*
Darren is a zoologist, vertebrate palaeontologist and science writer. His latest book is Evolution In Minutes *(£9.99, Quercus).*

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"There's no evidence from dietary or ecological studies that gulls are becoming more predatory"

SAVE OUR SNACKS

You're sitting by the sea, eating lunch, when suddenly you spot a seagull eyeing up your chips. Perhaps you try to shoo it away or shelter your plate in case of a sudden attack. But researchers at the University of Exeter have found that the best way to protect your food is to stare the gull down. The team studied herring gulls' thieving behaviour in Cornwall with the help of a clear bag filled with chips. Only a small number of gulls attempted to snatch the food, and those that did were more willing to make a move when the human was looking away. The gulls tried to grab the chips on average 21 seconds faster when they were unattended than when the human was staring at the bird. Whether gulls avoid the gaze of large mammals or simply have had bad interactions with humans in the past, the team says that this simple change could save a lot of food from seagull theft.

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BUILDING FOR THE FUTURE

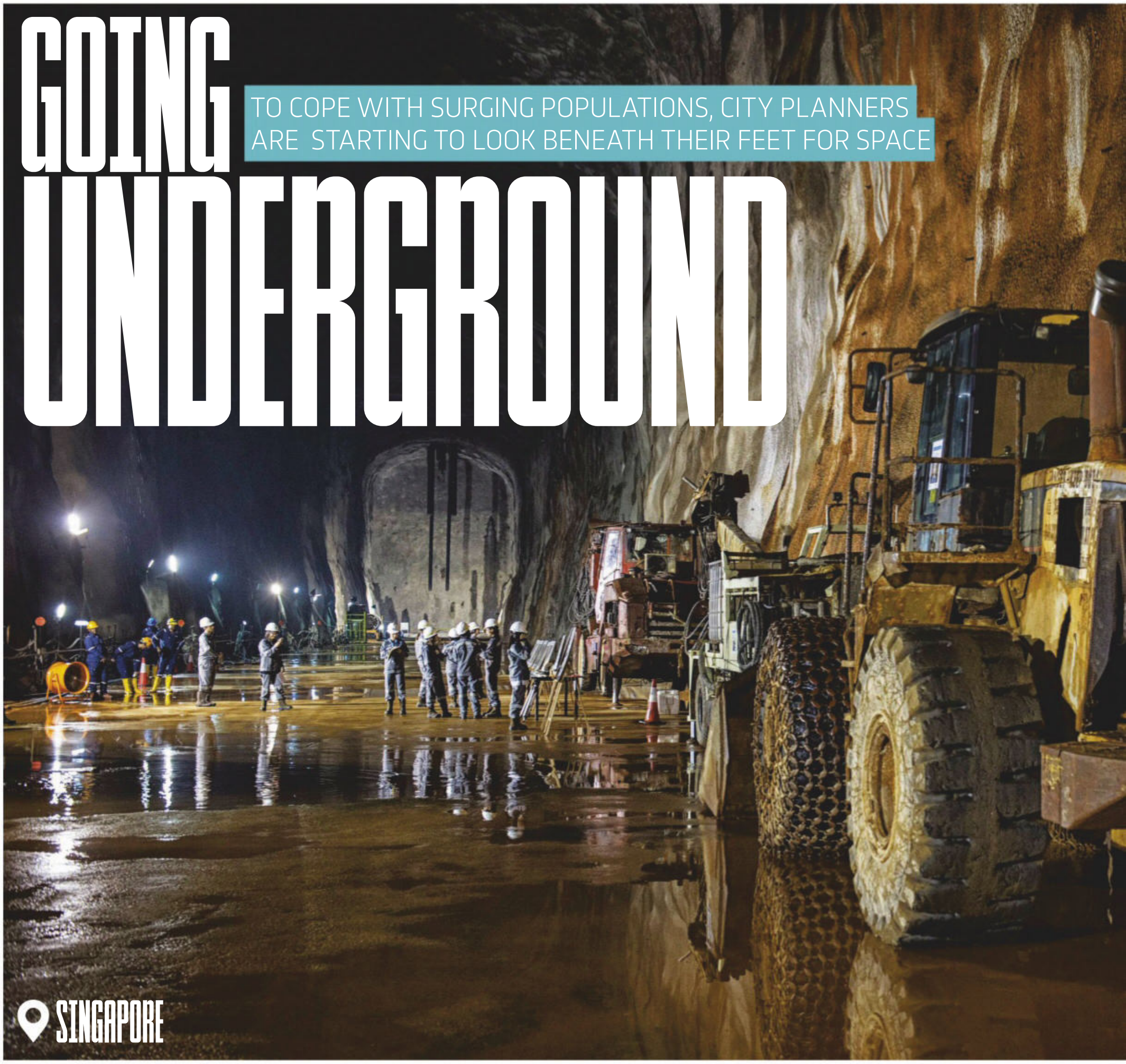
BY ABIGAIL BEALL

As overpopulation and climate change take their toll on our cities, engineers and urban planners are adapting their designs to cope with an uncertain future

STEFANO BOERI ARCHITETTI

GOING UNDERGROUND

TO COPE WITH SURGING POPULATIONS, CITY PLANNERS ARE STARTING TO LOOK BENEATH THEIR FEET FOR SPACE



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As the world's population continues to rise, space is becoming scarcer, and cities are looking for new places to host their residents. For Singapore – the world's third most densely populated country and home to nearly six million people – the answer is to head downwards.

Climate change and rising sea levels mean that reclaiming land is no longer a sustainable option for Singapore. Instead,

"Moving transport beneath the surface will help people escape Singapore's weather"

Jurong Rock Caverns in Singapore are 130m beneath the surface and will be used to store liquid hydrocarbons such as crude oil

the country is looking to create an underground city. Earlier this year, Singapore's Urban Redevelopment Authority published its draft master plan, setting out what the next 15 years are going to look like. So far, the equivalent of £10.7m has been invested in the research and development of underground tech. Laws have been changed regarding home ownership, so people only own the land as far down as their basement, to free up space beneath houses for development.

People won't be living underground at first, the authority says. Instead, the city will start by moving storage, utilities, transport and industrial facilities underground, freeing up space above ground for residential and commercial uses.

Currently, Singapore uses underground spaces for transport and cooling systems, which go down to 20m. A deep tunnel sewage system for transporting waste water and sewage is planned for 20m to 50m. "For deeper space of more than 100m, more heavy-duty functions such as ammunition storage and caverns for petrochemical storage could be created," says Sing Tien Foo, director of the Institute of Real Estate Studies at the National University of Singapore. One major planned development is the Jurong Rock Caverns, which can hold about 1.5 million cubic metres of crude oil and petroleum.

At the country's airport, Changi, a four-in-one transport hub will host three train depots and one bus depot by 2024, all underground. This will help the country to double its train network by 2030, with all additional railways underground. Moving transport beneath the surface will also help people to escape Singapore's weather, which is seeing rising heat, humidity and rainfall as a result of climate change.

In order to make the most of its subsurface environment, Singapore first needs to understand what's down there at the moment. Currently, Singapore's Building and Construction Authority is developing a 3D geological model using laser scanning, which will be collated into a central database to help map and plan the underground space.

Prof Kevin Curran, a cyber security expert at Ulster University, says that technology is going to be key in allowing this kind of eco-city to develop. For example, air quality will become an important factor that will need constant monitoring, as underground air isn't circulated as easily as air above the surface. "Sensor-enabled devices are already helping monitor the environmental impact of cities around the world, collecting details about sewers, air quality, and garbage," say Curran. Underground cities might have smart rubbish bins, for instance, which send an alert when they need to be emptied, and smart lighting, which only comes on when traffic or pedestrians are approaching.

Although much of Singapore might be underground by 2030, it will be a little longer before people are living there. "Deep underground construction is costly," says Foo. "There's complexity associated with access, ventilation and fire safety.

"The use of the underground space for residential and commercial uses has not been planned yet," he adds, "but the feasibility could be evaluated in the future, if more land is required."

LIFE AT SEA

AS SEA LEVELS ENCROACH ON THE LAND, COULD WE MOVE PEOPLE TO THE OCEANS?

In 2007, Marc Collins Chen was working as the minister for tourism in French Polynesia when reports started to emerge that the Pacific islands would be under threat from rising sea levels in the coming decades. "There wasn't consensus around when this would happen," he says. "But there was a sense of doom."

Today, Chen is CEO of Oceanix, a company based in Hong Kong that's developing concepts for floating cities. He's now been working on the problem for 12 years. "If you're a Pacific Islander and many of your islands are at sea level, you have to look at a solution," he says.

Earlier this year, Oceanix announced a collaboration with the Bjarke Ingels Group (BIG) and MIT's Centre for Ocean Engineering, creating a concept for a city of 10,000 people. It was unveiled as part of the UN's New Urban Agenda, a plan to create ways for the world's growing population to live more sustainably.

The 10,000 figure is an estimate, says Chen, and the way the city works means it will be able to host as few or as many people as necessary. The city will be made up of floating, roughly triangular platforms, each around two hectares in area and home to 300 people. Each platform, or 'neighbourhood', will generate its own renewable electricity from the waves and Sun, and the population can be increased by adding more of these modular platforms.

Alongside renewable energy, the city will grow its own plant-based food, and treat and reuse all waste water. "If you wanted to feed everybody with beef and chicken, you'd need so much surface area and freshwater," says Chen. "It'd become economically unfeasible."

The platforms will be secured to the seabed with biorock, which is a material already being used to create artificial reefs around the world. A low-voltage electrical current is passed through a steel frame, which electrolyses the seawater around it and causes charged particles ('ions') to build up on its surface, coating the steel in a rocky substance that's as strong as concrete.

Making sure the cities have a positive impact on the environment is crucial, Chen says. The UN uses 'ecological footprints' to measure the impact people have on the natural world, measured in global hectares per person. At current population levels, our planet has only 1.7 global hectares (gha) of biologically productive surface area per person. At the moment, the UK has a footprint of 7.9 gha per person, which means we're using more than we have. As the world's population increases, we need to be reducing our individual footprints. Chen says that Oceanix could have a footprint of as little as 0.5 gha per person, helping to reduce the strain on our ailing planet.

This might all sound quite far-fetched, but Chen believes it will happen, and soon. The company is aiming to have a prototype of the floating city in place within the next two and a half years, although the location has not yet been pinned down.

Residents will walk, cycle or boat through the city, with solar-powered ferries transporting them to the mainland

BJARKE INGELS GROUP

OCEANIX


All buildings will be lower than seven storeys (to windproof them) and made from locally-sourced materials such as bamboo
Six villages will connect to form a city of 10,000 residents, spread across 75 hectares
A large, protected harbour will be formed in the heart of the city. The six innermost neighbourhoods will include a public square, marketplace and centres for spirituality, learning, health, sport and culture
Villages will be composed of six platforms around a small, central harbour
Individual platforms, or neighbourhoods, will be two hectares in area and home to up to 300 people
Each neighbourhood will generate its own renewable electricity through technologies such as solar roofs and wave energy converters

GARDEN STATE

CAN FOREST CITIES HELP TO MOP UP OUR POLLUTION?

Once mature, the trees and plants will help absorb 58 tonnes of airborne pollutants and around 10,000 tonnes of CO_2 per year, and create 9,000 tonnes of oxygen

STEFANO BOERI ARCHITETTI

Traditionally, the more people in a city, the fewer trees there are. To create space for houses, offices and other buildings, nature takes second place. But, if the architect Stefano Boeri has anything to do with it, this will soon be changing.

Boeri has designed a forest city, to be created in the north of Liuzhou – a metropolis in the Guangxi region in southern China. This mountainous area was chosen to be "a city where living nature is totally intertwined with architecture," according to Boeri. Instead of completely getting rid of the trees to build houses, the city's design accommodates the surrounding greenery. Homes and commercial buildings will be covered with trees, with gardens on the balconies of every floor, and rooftops that are home to miniature forests.

"I have been working on the idea of urban forestation for years," says Boeri. "In those areas of the planet where it is still necessary to build new cities, we are planning real forest cities for a maximum of 150,000 inhabitants."

The Liuzhou Forest City will be connected to central Liuzhou via a railway line and a road. It will be home to 30,000 people, and include commercial and recreational spaces, two schools and a hospital. On top of this, the vegetation will absorb carbon dioxide and pollutants, as well as releasing oxygen into the atmosphere.

Development is well underway for the forest city. "Our masterplan for a forest city in Liuzhou has been approved by the local government," says Boeri. Now, the government is starting the process of selling land to interested developers. "The current phase is still ongoing for land selling," says Boeri. Building is expected to begin in 2020. At the same time, the firm has replicated the concept in Lishui, a city in the southeast of China. The masterplan has also been given the thumbs-up by local governors here, and the developer is collecting funds to launch the project.

If the Chinese cities prove successful, Boeri hopes that the same concept in other places with different climate conditions, such as Mexico and north Africa," he says.

And there is science behind the idea of planting trees to halt climate change. A study earlier this year by scientists at ETH Zurich found that planting at least a trillion trees around the world could lock up 205 billion tonnes of carbon, once the trees are mature, helping to offset the effects of releasing greenhouse gases into the atmosphere. SF

by ABIGAIL BEALL *(@abbybeall)*
Abigail is a science journalist, based in Leeds.

LIUZHOU, CHINA


NINE

NINE

Beyond Neptune, a handful of small worlds are moving in harmony. Astronomers think they might be dancing to the tune of a third world lurking in the darkness, one that's four times bigger than Earth and significant enough to be named our Solar System's ninth planet. Now they think they know exactly where to look for it...

by COLIN STUART

ILLUSTRATION: MAGIC TORCH

Look up at the night sky and find the famous three stars of Orion's Belt. Then extend the line between them up and to the right towards the constellation of Taurus, The Bull. Halfway between them sits a small patch of otherwise unremarkable sky that could well be home to one of the most famous finds in astronomical history – a ninth planet orbiting the Sun. It isn't every day a new planet is discovered in the Solar System. In fact, by one measure, it has only happened twice before in all of human history with Uranus (1781) and Neptune (1846). All the other planets have been known since antiquity and were never really 'discovered'. Objects such as Ceres (the largest asteroid) and Pluto were once deemed part of the planet club, but have since had their membership revoked. William Herschel, Urbain Le Verrier, Johann Gottfried Galle and John Couch Adams are the only astronomers to ever find a new planet that is still considered as such.

That elite list may soon be about to grow. CalTech astronomers Mike Brown and Konstantin Batygin are among the frontrunners to join it. Back in 2016 they went public with the radical notion that the roll call of planets orbiting the Sun isn't finished. They had noticed a handful of small worlds beyond Neptune behaving mysteriously, and considered that perhaps a ninth planet could account for their strange motion. "We were confident that another planet could explain the features of the outer Solar System," says Batygin. They've been scouring the sky for this object, but so far it has escaped them. For now, this potential world goes by the moniker of Planet Nine. If and when it is discovered, it will be named after a Roman or Greek deity, just like the other planets.

LONG-DISTANCE RELATIONSHIP

Planet Nine's suggested existence is based on observations over the last decade with telescopes big enough to peer into the murky environs beyond the eight known planets. Studying this under-explored wilderness is a real challenge. We only see thanks to reflected sunlight, and for these trans-Neptunian objects (TNOs) that light has to undergo quite a journey. The odyssey starts at the Sun, then travels out to a distance of more than 4,500,000,000km, before bouncing off an object and making the return trip to the Earth almost all the way back to the start. That light is also fading all the while, making it very faint and requiring a big telescope to collect it. Take the 600-kilometre-wide object known as 2012 VP113. It sits 80 times further from the Sun than the Earth, meaning the light we see reflected from it is around 40 million times dimmer than normal sunlight. Despite travelling at 300,000 kilometres per second, light takes nearly a day to cover the full distance from the Sun to VP113 and back to the Earth.

It was the discovery of VP113 by astronomers Scott Sheppard and Chad Trujillo in 2014 that first flagged up the possibility of an undiscovered

"WE WERE CONFIDENT THAT ANOTHER PLANET COULD EXPLAIN THE FEATURES OF THE OUTER SOLAR SYSTEM"

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TOP: The five confirmed dwarf planets in our Solar System and their moons. From left to right: Pluto; Eris; Makemake; Ceres; Haumea

MIDDLE: The region of sky between Orion's Belt (yellow circle) and Taurus (white circle) is the search area for Planet Nine

BOTTOM: Artist's impression of Planet Nine

planet. They are another team currently hunting down Planet Nine. Closer scrutiny of VP113's path around the Sun showed that it shared orbital characteristics with another TNO called Sedna. The angle at which they approach the Sun is eerily similar. Our best theories of Solar System formation say that for each object this tilt should be random. So the fact that these two objects match arouses suspicion. "They're like the fingerprints and broken glass of a crime scene," says Megan Schwamb from the Gemini Observatory in Hawaii and co-discoverer of several TNOs. "Who did it?". One explanation is to point the finger at a ninth planet, whose gravity is pulling on these objects and organising their orbits. To be doing that it would have to be several times the mass of the Earth. It wouldn't be the first time we've found a new planet this way. After Uranus was discovered, discrepancies in its orbit were put down to the tug of another planet even further out. Sure enough, when astronomers calculated where this planet would be they discovered Neptune. Now teams of astronomers including Brown, Batygin, Sheppard and Trujillo are trying to do the same with Planet Nine.

HIDE AND SEEK

So far the planet remains stubbornly out of view, but the search has cemented the evidence that it is really there. In the process of trawling the outer Solar System, astronomers have uncovered new TNOs. We now know of 14 objects clustered together more than 230 times further from the Sun than the Earth. This includes an object nicknamed The Goblin, discovered by a team of astronomers including Sheppard and announced in October 2018. It's a 300-kilometre-wide TNO on a highly elongated 40,000-year loop around the Sun. The more of these objects that we find sharing similar tilts, the stronger the case for Planet Nine becomes.

But there are alternative explanations. The leading one is that these copycat orbits are nothing more than observational bias. There are thought to be millions of TNOs out there that we haven't found yet, all with random orbits. It could just be a fluke that we've happened upon the handful that do share similar paths around the Sun. If this were true, Planet Nine would be a figment of our ▶

FAMOUS OBJECTS BEYOND NEPTUNE

SEDNA

Discovered by Mike Brown, Chad Trujillo and David Rabinowitz in 2003, Sedna was one of the objects that forced astronomers to re-evaluate Pluto's planethood. It takes 11,400 years to orbit the Sun, crawling along at an average speed of just one kilometre per second. Sedna will make its closest approach to the Sun in 2075–2076, providing a once in an 11,400-year opportunity to get the best view of this world named after the Inuit goddess of the sea.

2012 VP113

This object is often nicknamed 'Biden' after Joe Biden, who was the US vice-president at the time of its discovery at the Cerro Tololo Inter-American Observatory in Chile. At 600 kilometres wide, astronomers believe its pink colouration is due to the way cosmic radiation has shaded its surface, which is made of water and/or methane ice. It doesn't get as close to the Sun as Sedna, nor as far away. Sedna and Biden were the original basis for the Planet Nine idea.

imaginations. But in January 2019 Brown and Batygin published new research attempting to quantify how likely this is based on the latest TNO discoveries. Their answer? Just 0.2 per cent. "That's our most conservative estimate," says Batygin. A ninth planet, they claim, is the only existing explanation for what we see in the outer Solar System.

SCOURING THE SKIES

That doesn't mean finding it is easy. All searches so far have failed to spot the planet. The hunt is not helped by the fact that there are only a handful of telescopes in the world capable of seeing it. Not only do you need a large aperture telescope to collect the faint light, you also need one equipped with a camera with a wide field of view. Brown is using the 8.2-metre Subaru telescope in Hawaii to hunt for it, while Batygin is busy crunching the numbers. "The search area is 800 square degrees of sky," says Brown. That's about the same as 3,200 full Moons. A telescope with a narrow view would just take too long to cover this vast expanse.

It's not a two-dimensional patch of sky either, but three-dimensional. We also don't know Planet Nine's exact distance from the Sun. If it is near it will be brighter and if it's further away it will be dimmer. When it comes to the brighter end, Brown says they've already covered nearly all of the sky where it might be hiding without success. "That's surprising to me," he says. "That would have been the most reasonable guess of what Planet Nine would be like."

The findings are all the more unexpected when Batygin's latest computer modelling is taken into account. "We've performed thousands of new computer simulations in the last 18 months," he says, all to understand more about where Planet Nine could be. According to Batygin, the upshot of those calculations is that "Planet Nine is smaller in all parameters by a factor of two

"A NINTH PLANET, THEY CLAIM, IS THE ONLY EXISTING EXPLANATION FOR WHAT WE SEE IN THE OUTER SOLAR SYSTEM"

GETTY IMAGES

THE GOBLIN

Named because it was discovered close to Halloween, The Goblin was first observed on 13 October 2015 using the Mauna Kea Observatory in Hawaii. It took three years to track it in sufficient detail to pin down its orbit and announce the discovery to the public. The Goblin's highly elongated orbit carries it from roughly twice Pluto's distance from the Sun all the way out to 30 times further than that. It's about as bright as one of Pluto's smaller moons.

FAROUT

Astronomers like to keep things simple where they can, as illustrated by the nickname of this object found on 10 November 2018. A name like FarOut marks that, at the time of its discovery, it was the furthest object ever found in the Solar System. Unfortunately this won't be its official name. Looking back at older photographs actually shows that FarOut had been captured before in 2015 and 2017. Like VP113, it appears to be pinkish in colour.

FARFAROUT

FarOut didn't hold its crown as a record breaker for long. In February 2019 a team led by Scott Sheppard announced the discovery of an object even further out – nicknamed FarFarOut.
This time it is 140 times further from the Sun than Earth (or 21 billion kilometres). Both objects have been found so recently that their orbits are still being determined to see if they support the Planet Nine theory.

Mike Brown (left) and Konstantin Batygin (right) are searching the skies for objects beyond Neptune, including Planet Nine

HEAD IN THE CLOUDS:
The Subaru Telescope on top of Hawaii's Mauna Kea is being used to search the skies for Planet Nine

"NATURE HAS NO OBLIGATION TO YOU. LOOK AT GRAVITATIONAL WAVES – THEY TOOK 100 YEARS TO FIND"

compared to our original estimates". Its orbital period is now thought to be 10,000 years rather than 20,000. It is five times the mass of the Earth, not 10. Despite being smaller, its shorter orbit would make it about two and half times brighter than the original 2016 estimates.

THE NET IS CLOSING

So how come Brown still hasn't found it, despite trawling the whole area at the brighter end? "We don't know its albedo and that's the key parameter," says Brown. An object's albedo is a measure of how much sunlight its surface reflects back into space. "It could either be a super-cloudy, bright object or a dark ice ball covered in junk with a low albedo." The fact it hasn't been found yet suggests it is the latter. If a dull surface is making it dimmer, finding Planet Nine will take more time. "We've covered about 50 per cent of the sky in that range," he says.

So the net is closing, but it is a laborious process. "The main difficulty is sustaining such an intense search for many years," says Brown. Planet Nine's predicted position out between Orion's Belt and Taurus is both a blessing and curse. Orion is part of the winter sky, which means that astronomers are restricted to searching for it during that season. In the summer it is part of the daytime sky and therefore undetectable. On the plus side, winter nights are longer, but the emphatic downside is that in recent years the winter weather in Hawaii has been horrendous. Batygin recalls one occasion where he was driving up the volcano to the telescope with hailstones the size of golf balls slamming into the car. On another occasion the weather looked clear, but Brown arrived at the telescope to find the door to the telescope was frozen shut. "We've had every sort of obstacle you can imagine," says Brown. Other roadblocks have included volcanic eruptions, earthquakes and sulphur dioxide fumes. "It's frustrating," he says. "[I'd] like to find it and move on to something else." With winter now over, this season is done and the search will have to wait until the Earth moves back round to the favourable side of the Sun. Batygin sums it up nicely: "Nature has no obligation to you," he says. "Look at gravitational waves – they took 100 years to find."

Hopefully we won't have to wait quite that long. If the current searches fail, there's hope on the horizon in the form of the Large Synoptic Survey Telescope (LSST). Currently under construction in Chile, its 3.2 billion pixel camera will be capable of photographing an area of sky the size of 49 full Moons at once. It's due to start operation in 2022. Even if it doesn't find Planet Nine right away, it is expected to discover hundreds of new TNOs. If their orbits also share the tell-tale alignment, then that would both strengthen the case for Planet Nine and point astronomers towards where to find it. According to Schwamb, the Planet Nine hypothesis is an answerable question. "It is not going to be a mystery forever," she says.

A deeper puzzle is how Planet Nine got there in the first place. How does a planet five times the mass of the Earth end up marooned up to 20 times further from the Sun than Neptune? The most likely explanation is it formed in the inner Solar System with the other eight planets, before some event threw it out into the depths of space. Even before astronomers found evidence for Planet Nine, computer simulations of the Solar System's formation were hinting at a missing planet. Starting with five giant planets resulted in a Solar System that looks more like ours today than those that started with just four. The only trouble was that there was no other evidence that this extra planet ever existed. Yet if the current frenzy of activity confirms the existence of Planet Nine, it is almost certainly this missing world. Its discovery would mean more than just another planet on the list: it could be the key to understanding why our Solar System looks the way it does today. SF

by COLIN STUART
(@skyponderer)
Colin is an astronomy author. Get his weekly space newsletter at ***colinstuart.net/newsletter***

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COMMENT

I HAVE A CONFECTION...

Could my naughty chocolate habit actually be good for my brain?

One of my favourite foods is chocolate, especially the milky stuff, but I will eat dark chocolate. So this particular headline cheered me up no end: "People who eat dark chocolate are less likely to be depressed". It was based on a study carried out by researchers from University College London, published in the journal *Depression & Anxiety*. They compared the chocolate-eating habits of more than 13,000 adults (based on dietary questionnaires), with their depression scores (based on something called the Patient Health Questionnaire).

After adjusting for confounders such as height, weight, marital status, ethnicity, education, income, physical activity, smoking, etc, they found that eaters of dark chocolate had 70 per cent lower odds of being clinically depressed than those who reported not eating chocolate at all. Dr Sarah Jackson, lead author of the study, was rightly cautious about claiming too much. As she explained, from this sort of a study you can't infer causality. It could be that when people get depressed they lose interest in eating chocolate (which strikes me as a bit implausible), "or there could be other factors that make people both less likely to eat dark chocolate and to be depressed."

But let's assume, for the moment, that eating dark chocolate might enhance your mood. What could be the mechanism? Dark chocolate has a high concentration of flavonoids – these are antioxidants which have been shown to reduce inflammation. Chocolate also contains a surprising amount of fibre. The dark chocolate I am currently staring at is 10 per cent fibre, while the cocoa powder in my cupboard says it is 30 per cent fibre.

"Antioxidants and fibre in dark chocolate can boost levels of good bacteria in the gut"

This combination of flavonoids and fibre have been shown to boost levels of 'good' bacteria in the gut. In turn, these bacteria produce short-chain fatty acids, which have a powerful anti-inflammatory effect. As there is mounting evidence that depression, at least in part, is due to inflammation in the brain, you can begin to put together a plausible case for dark chocolate mediating depression via the microbiome.

There are no randomised controlled trials showing that dark chocolate really does improve depression, but there was one that showed it could boost blood flow to the brain and other organs. In a small study published in the journal *Cardiovascular System,* Portuguese researchers took 30 healthy adults and allocated them to either eating eight grams – about one small square – of 70 per cent cocoa chocolate a day for a month, or to a control group. Those eating the chocolate saw their arterial blood flow increase, on average, by over 50 per cent.

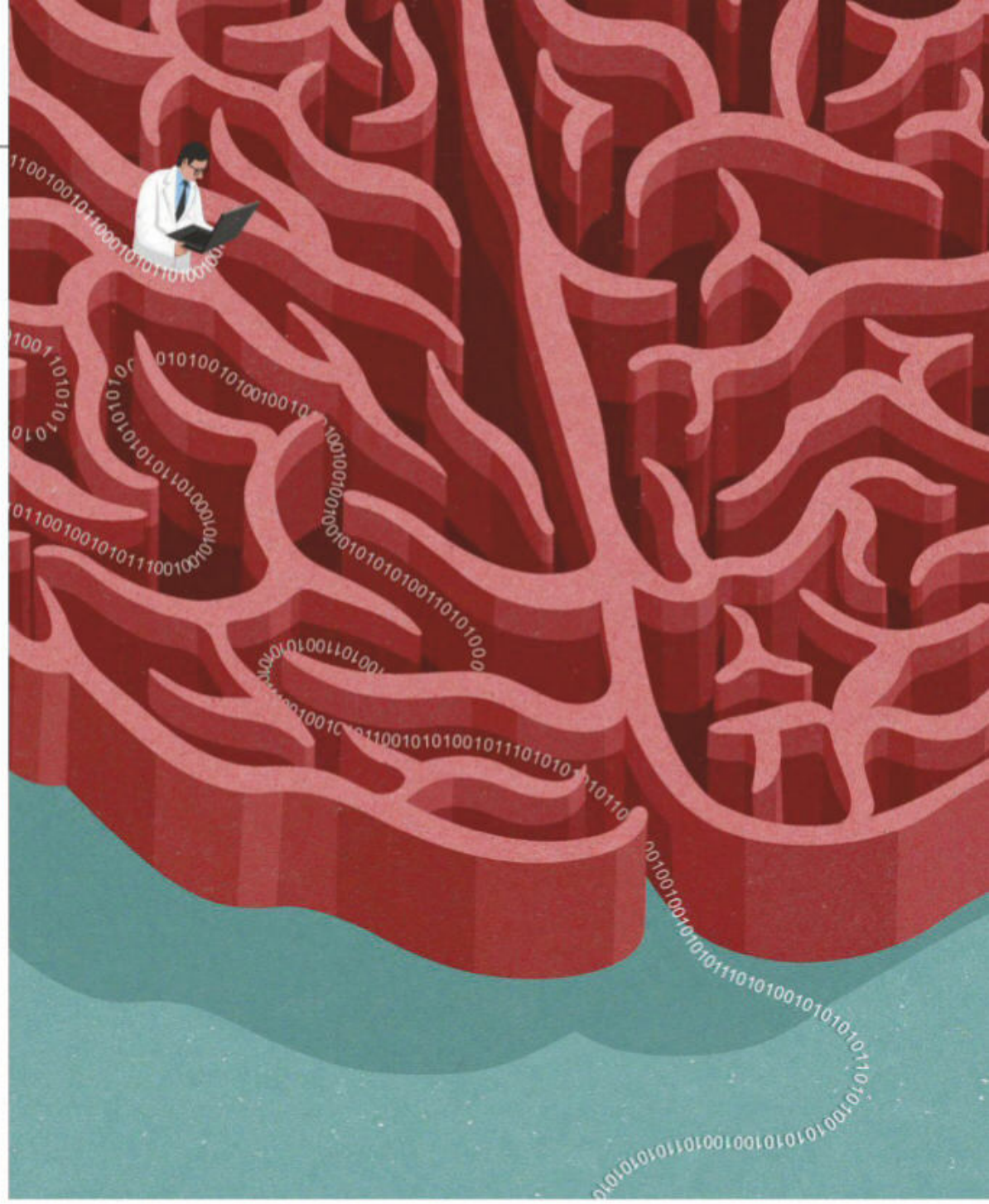
While I can't see dark chocolate being prescribed for depression or heart failure any time soon, it does make me feel better about having a nibble every now and then. **SF**

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor.* His latest book is *The Fast 800* (£8.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: SERGIO MEMBRILLAS



COMMENT

THE DEVIL'S IN THE DATA

No wonder algorithms find humans slippery – evolution's gifts don't come cheap

Within 50 years, there will be artificial intelligence that is indiscernible from a human being. Discuss.

I'm not talking about a Turing test for a computer's ability to deceive us; tech can already do that really well. Think of a real-life, embodied version of Scarlett Johansson's character in the Spike Jonze film *Her*. A programmed artefact that, if we met it in the street, would be so convincing that we couldn't tell the difference between us and it.

Full disclosure: I don't believe it'll happen, and certainly not in the next half century (even if we could make convincing synthetic bodies). I've spent too long investigating the complexity of the mind to imagine a computer programmer has cracked our code so quickly. We have too many nuances and contradictions to be reduced to a bunch of 1s and 0s.

And yet, I've had to fight my corner. There's a lot of financial and emotional investment in the idea of a human simulacrum. Today's 'mad scientists' are computer developers, empowered by popular culture and promises of delivering this fantasy.

Sometimes we're told they've done it. Not long ago, the hot ticket was 'sentiment analysis': trawling for keywords in our online content to guesstimate whether we're currently happy or sad about something.

PORTRAIT: KATE COPELAND ILLUSTRATION: JOHN HOLCROFT

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.

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"There's a lot of financial and emotional investment in the idea of a human simulacrum"

Lately, big data has been hailed as the key to unlocking the essence of humanity. In both cases, as much data as possible is thrown into a bag, shaken up, and, hey presto, we know what you're going to think and do next.

But in trying to mimic the black boxes of our minds with algorithms, assumptions are being made. One is that the words we use mean what the dictionary says they do; another is that we behave online like we do offline. Earlier this year, in research published in *Psychological Science In The Public Interest,* psychologist Lisa Feldman Barrett and her colleagues investigated whether our facial expressions predict our emotions, I'll sum up: they don't. At least, not consistently enough for anyone to base an employment decision, an arrest, or a health diagnosis upon them. And that's a problem, because these are areas where facial recognition systems are now being deployed, with real-life implications.

The research looked at more than 1,000 studies that tried to link facial expression with anger, sadness, disgust, fear, happiness and surprise. The results were clear: context is more important than what our facial muscles are doing. We might scowl when we're angry, or when we have stomach ache. We might smile when we're happy, or because we're afraid.

So, the new hot ticket – facial recognition – is based upon a flawed premise: that we can take human experience out of context and plop it into an algorithm. And that applies to many technologies of this kind.

We have evolved the ability to extract the signal from the noise. It'll take more than 50 years of trial and error to duplicate that. SF

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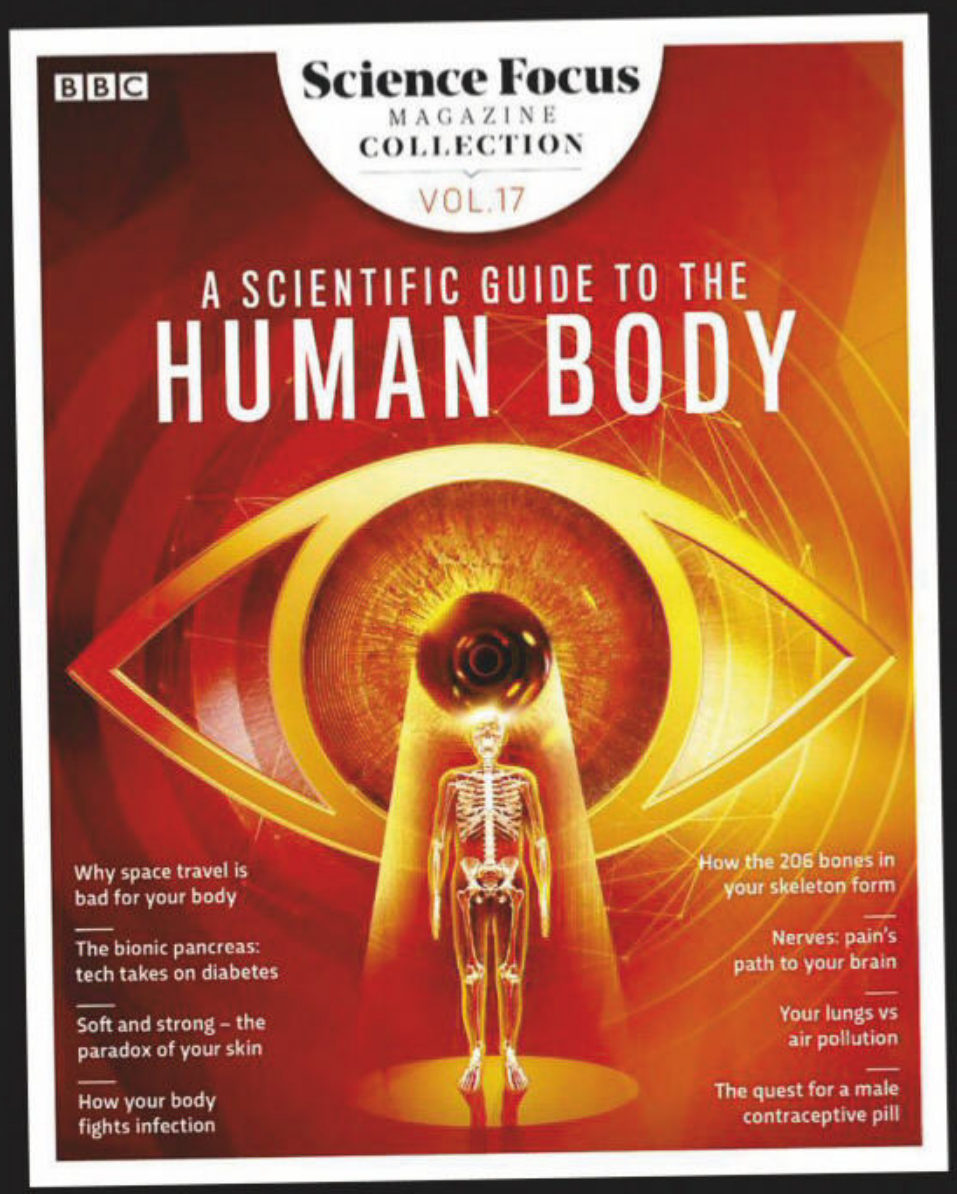

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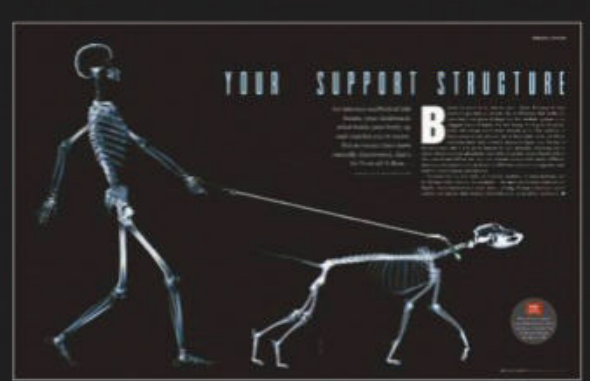

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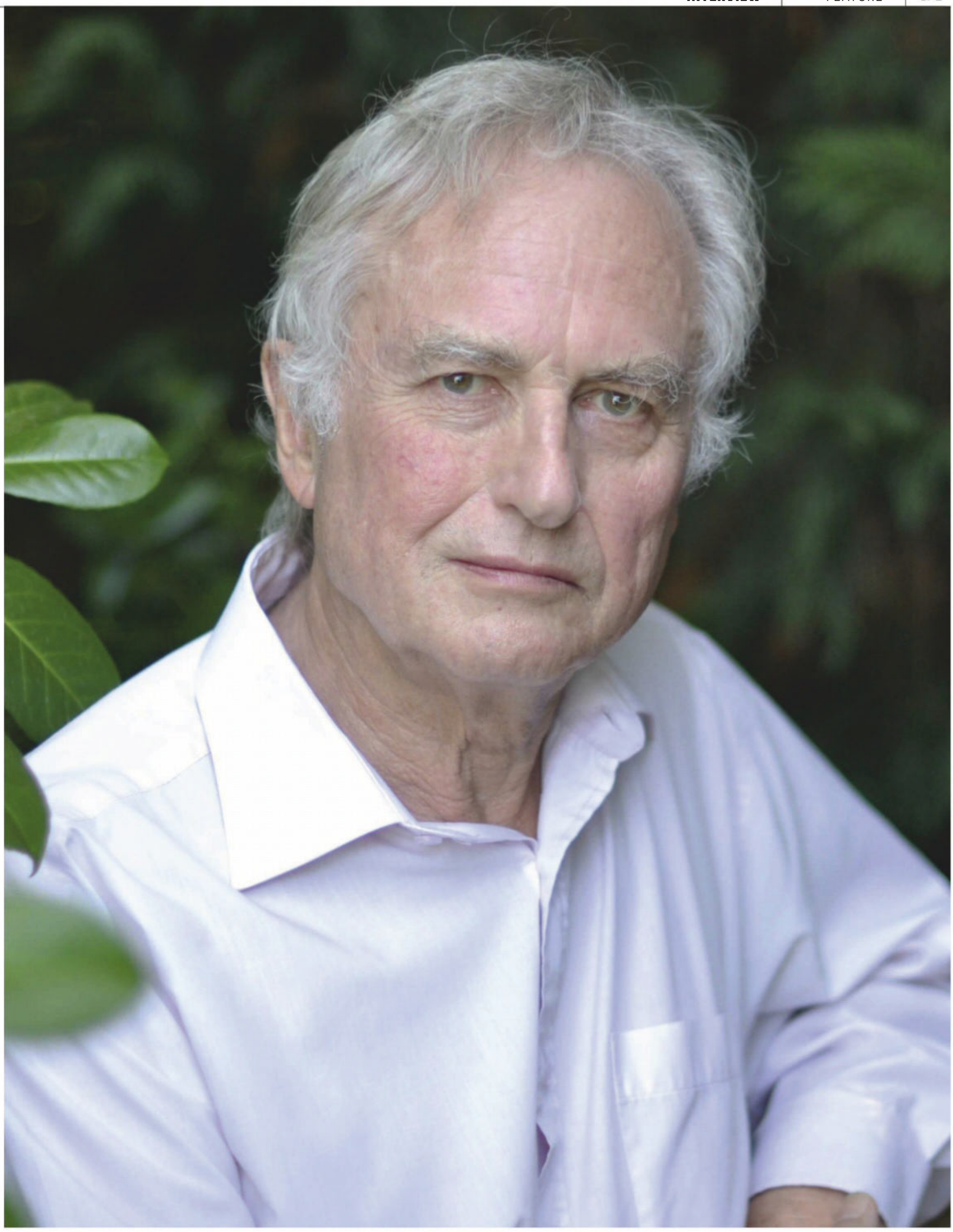
BEYOND BELIEF

Known for his opinions on atheism and his books on evolution, **RICHARD DAWKINS** is considered one of the top British intellectuals of the 21st Century. Ahead of the release of his new book, he tells **AMY BARRETT** how he lost his faith and found a new community with science

JANA LENZOVA



“I suppose one explanation for flat-Earthism is a kind of fellowship ... The internet provides the club room where you can meet people who have dotty ideas like you”

THIRTEEN YEARS AGO YOU PUBLISHED *THE GOD DELUSION*. WHAT WERE YOU HOPING TO ACHIEVE WITH YOUR NEW BOOK, *OUTGROWING GOD*?

I actually wanted it to be a children’s book, but the publishers weren’t keen so they pushed up the age scale of it. I think of it as a book for young people, but I would hope that anybody could read it. I’ve been aware that some people have asked for an easier version of *The God Delusion*. It isn’t that. I think it’s a bit easier, the language is a bit easier, but it doesn’t really overlap much. It’s not *The God Delusion-lite* – the chapters are about different things. Though I hope it is light.

WHY DO YOU THINK WE WANT TO BELIEVE IN THE SPIRITUAL?

A lot of it, I think, is people just don’t know better. In many cases, they simply don’t understand evolution. They think it’s the theory of chance. If you think it’s a theory of chance, then obviously it [evolution] can’t work. Only a fool would think you could put together the eye by chance.

I suppose there’s a strong allure to religion. People want to believe; perhaps they’re frightened of dying or perhaps they want to be united with their loved ones after they die and so on. There’s a motivation towards religion from that point of view, and therefore people are eager, in a way, to be seduced by the ‘design by watchmaker’ argument.

THE WATCHMAKER ANALOGY IS ONE YOU’VE ARGUED AGAINST BEFORE. CAN YOU EXPLAIN IT FOR US?

It originates from William Paley [an English clergyman and philosopher, born in 1743]. He says that if you were walking along and you found a stone, the stone doesn’t require explanation – it’s much like any other stone. But if you find a watch and you open it up, you’ll see all the cogwheels and the screws and the springs. Obviously, someone had to make it. It had to have a designer, a watchmaker. Paley said, reasonably enough for his time, that living things must have a watchmaker as well. There must be a divine designer.

That was a difficult argument to refute, and when Darwin was an undergraduate, he fell for it. He thought it was wonderful. But of course, we now know that later on Darwin provided the total refutation of it. I think it always was rather a bad argument, but nevertheless, in the 18th Century nobody thought of an alternative. So they stuck with it.

HOW DID DARWINISM REFUTE THE WATCHMAKER ANALOGY?

Well, living watches – things like eyes and hearts and kidneys – are put together by the slow, gradual, step-by-step process of natural selection. It’s a very, very different process from the way a watch is made. A watch is designed on a drawing board, and put together by an intelligent watchmaker, all in one go. Whereas living things are put together over millions of years – or even billions of years if you start from the beginning – by a process which achieves remarkably watch-like results. Results that look exactly as though they have been designed, but not quite, because in some respects, it’s bad design. It’s design that you wouldn’t do if you were a human watchmaker. Things like the eye, for example, with the retina being backwards.

That’s what you get when you get design by natural selection. You get bad design, because it has its history written all over it.

WE SEEM TO BE SEEING A RISE IN THE NUMBER OF PEOPLE WHO ARE ‘ANTI-EXPERTS’, REJECTING THINGS LIKE VACCINES, THE MOON LANDINGS AND CLIMATE CHANGE. WHY DO YOU THINK THAT IS?

It’s mysterious, because the evidence for the Moon landing is utterly overwhelming. We’ve even got flat-Earthers on the rise at the moment. The evidence for the Earth being round is so utterly incontrovertible – you have to wonder, what’s going on here?

I suppose one explanation for flat-Earthism is a kind of fellowship. People who perhaps have been a bit of a misfit in their life find a group of people who are also misfits, and they like to club together, and the internet provides the club room where you can meet people who have dotty ideas like you.

Richard Dawkins
(@RichardDawkins)
Richard Dawkins is a renowned evolutionary biologist and science writer who was born in Nairobi, Kenya, in 1941. He studied zoology at the University of Oxford, and went on to achieve master’s and doctorate degrees in the same subject. Richard rose to prominence after the publication of his first book, The Selfish Gene, *in 1976. Since then he has written more than a dozen science books, on top of numerous articles and journal papers, and was Charles Simonyi Professor of the Public Understanding of Science at Oxford University from 1995 to 2008. He famously appeared as a devil in an episode of* The Simpsons.

GETTY IMAGES

Dawkins at Oxford University in 1976 using computer-simulated mating calls to better understand how crickets chirp to one another

1

With the anti-vaxxers … there is widespread hostility to big pharmaceutical companies, and with some good reason actually. It would be easy enough, if you are heavily committed to criticising Big Pharma, to think that being an anti-vaxxer is a part of that. What we want is for people to think critically and clearly about each individual case and not lump things together if they're not really lumpable.

THE COMMUNITY THAT YOU TALK ABOUT, THE SORT THAT FLAT-EARTHERS FORM. IT'S ALMOST SIMILAR TO RELIGION…

I think it is. Not in every respect. It's not supernatural. So, once again, we mustn't lump things together too much, but there's a certain amount in common where it's worth making the comparison.

FOR THAT REASON – BECAUSE IT'S SUCH A COMMUNITY – COULD WE NEVER LIVE IN A WORLD WITHOUT RELIGION?

If it's really true that people need the sort of fellowship that religion gives them, then it should be possible to find it in different ways, and I think a love of science goes a long way; you can join other people with that.

Or you can just say, well, truth actually matters. And truth is more important than fellowship, than belonging to a community of like-minded people. I think a lot of people immediately jump into a feeling of 'how does that square with my group? My people? My club?' If we're left-wing, we think that everything's got to fit in with that; if we're right-wing, everything's got to fit in with that.

I would hope that people could learn to judge each truth-claim on its merits and not judge it whether it somehow fits in with their prior prejudices.

YOU HAVE ONE OF THE BIGGEST FOLLOWINGS OF ANY SCIENTIST ON TWITTER. WOULD YOU SAY YOU'RE A FAN OF SOCIAL MEDIA?

I'm not sure about social media. I'm a great fan of being able to look things up on the internet. I'm just bowled over with admiration for the vision of people who put it together, Tim Berners-Lee [the English scientist who invented the World Wide Web] and so on. I think it's probably outstretched even what they imagined would happen.

As for social media, I've been impressed by the negative things, like [investigative journalist] Carole Cadwalladr's uncovering of the truly shocking way in which Facebook was used to manipulate both Brexit and the Trump election. It's absolutely clear that Cambridge Analytica, and probably various other companies, shamelessly used masses and masses of personal information – about all of us, you, me and everybody – and sold that to the Trump campaign and the Brexit campaign, enabling them to target individual voters with particular propaganda tailor-made for them. They know what your likes are, your preferences are – probably more than you know yourself.

That's a highly pernicious effect of, above all, Facebook. I don't do Facebook myself – I do Twitter,

"The real reason why I'm opposed to religion is that it stunts the understanding of the wonderful world, the wonderful Universe in which we live"

1. Richard Dawkins at the Bluedot Festival in 2018

2. From left to right: chemist and Nobel Laureate Harold Kroto, retired cosmonaut Alexi Leonov, evolutionary biologist Richard Dawkins, former Queen guitarist Brian May, theoretical physicist Stephen Hawking and astrophysicist Garik Israelian on stage for the announcement of Hawking's Starmus medal for science communication in December 2015

3. A younger Richard Dawkins

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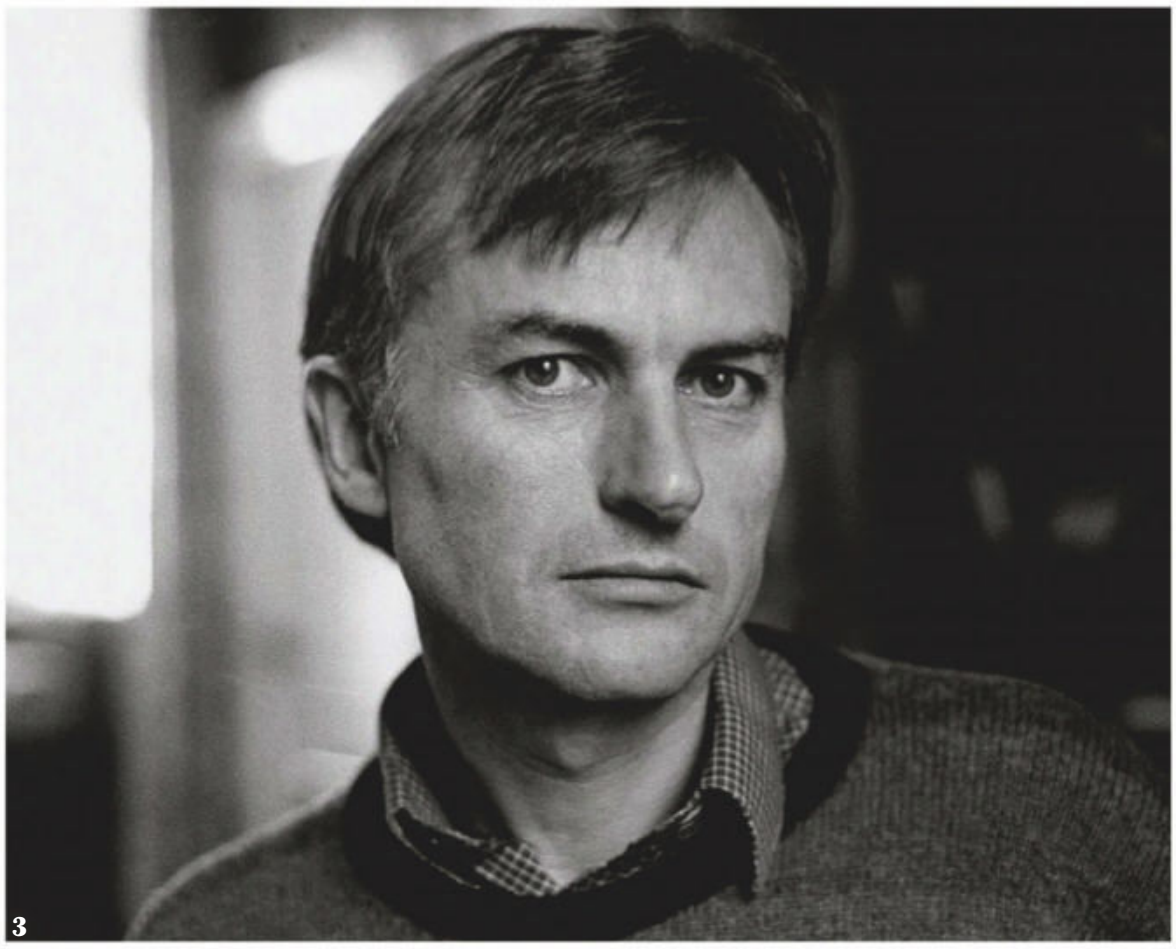

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which is pretty silly, but doesn't have the same capacity to be manipulated in this cynical, really disgraceful way.

WHO'S YOUR FAVOURITE PERSON TO FOLLOW ON TWITTER?

Well, I don't follow anybody at the moment, because I no longer do Twitter myself. It's done for me, I don't even have my own password. But when I did, I liked Stephen Fry, Ricky Gervais, quite a few others. People who do it with good humour.

AND HUMOUR CAN BE USED TO HELP DISCUSSIONS...

It can, yes, and sometimes I tweet things that are really designed to get a conversation going. Something that's maybe been puzzling me a bit, or I think that this scientific point is interesting and worth discussing.

A LOT OF YOUR BOOKS AIM TO START A CONVERSATION, DON'T THEY?

Very much so, yes. They do.

WITH *OUTGROWING GOD*, WERE YOU HOPING TO PROVIDE PEOPLE WITH A KNOWLEDGE THAT ALLOWS THEM TO STEP OUTSIDE OF THEIR COMFORT ZONE OF RELIGION?

Yes. Well, if it's a comfort zone, then I don't apologise for destroying it if I do destroy it. I mean, I do actually think truth is ultimately the most important thing.

Having said that, I definitely think that you can find a much better comfort zone than religion. I don't just mean destroying comfort zones for its own sake. I hope that science will provide a much better comfort zone. It's such a privilege to live in the 21st Century when we do know so much. There's a lot we don't know. But, compared to our ancestors, we are hugely privileged to know how old the Universe is. To know where we come from. To know we're a product of evolution. To know about the chemical elements that we're made of. It's just a wonderful, wonderful privilege, and I think it's such a shame to deny children that privilege, which I fear is what so much of religion does.

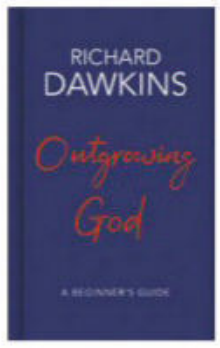
So, the real reason why I'm opposed to religion is that it stunts the understanding by children, and by anybody really, of the wonderful world, the wonderful Universe in which we live. SF

DISCOVER MORE

You can listen to our full interview with Richard in an upcoming episode of the Science Focus podcast ***sciencefocus.com/science-focus-podcast***

Tune in to BBC Sounds to listen to Richard Dawkins on Trust Me, I'm A Scientist *talking about the disconnect between science and society* ***bit.ly/Dawkins_science***

Richard Dawkins's latest book, Outgrowing God *(£14.99, Bantam Press), is out on 19 September. It challenges creationism, intelligent design and the idea that one must have faith to be good.*



SHOCK VALUE

Electroconvulsive therapy has a reputation as a violent – even barbaric – treatment for mental illness. But with clinics gradually closing nationwide, is the UK losing a life-saving therapy?

by HELEN GLENNY

On a cold Monday in May 2010, Karen escaped, in a panic, from her room in a Birmingham hospital's psychiatric ward. She arrived at a motorway flyover. Looking down, she watched the traffic, plotting for the perfect time to jump. The flashbacks had become too much. "My only purpose was to end my life," she recalls. "I did not want to be here."

Karen's descent into severe depression had started six months earlier, when her husband had been diagnosed with a life-threatening heart condition and she had dedicated herself to supporting him and their three kids. Her partner recovered and returned to work, but Karen began to struggle psychologically, and in the months that followed she isolated herself from her friends, became anxious and eventually stopped eating. After losing a dangerous amount of weight, Karen saw a psychiatrist, who admitted her to hospital.

Everyone thought the stress of her husband's illness was the sole cause of Karen's downward spiral, but it wasn't that simple. "Things came back that I'd been burying," she says. "I wasn't able to bury them any more." During an appointment with her psychiatrist in hospital, Karen spoke for the first time about a traumatic event from her childhood. When she was 14, she had been raped by a stranger on her way home from a friend's house. "I didn't tell anybody about it. It was a form of self-protection: if I didn't talk about it, it hadn't happened," she says.

After that revelation, flashbacks plagued her. "It was like going through it all over again, what I could feel, what I could see, what I could hear," says Karen. A week after that meeting with her psychiatrist, she took a step up onto the flyover's protective metal railing, ready to jump. Within seconds, two passing drivers pulled over, got out of their cars, and prevented her from jumping for long enough for the police to arrive and take her back to hospital.

BEYOND THE SHOCK

In the past year, more than 18,000 people have been hospitalised in the UK with depression. Many of those people have a severe, treatment-resistant form of the illness, meaning they haven't had any success with the usual treatments, like psychotherapy and antidepressants.

Some UK psychiatrists choose to offer these patients a treatment that's clouded in stigma and believed by many to be barbaric and ▸

ILLUSTRATION: EMMANUEL POLANCO

abusive: electroconvulsive therapy, or ECT. In 2016-17, around 1,700 people received ECT in England, Ireland, Wales and Northern Ireland. During the treatment, an electric current is passed through a patient's brain to induce a seizure. Proponents of ECT claim that it is the fastest acting and most effective treatment for severe depression, and argue that the stigma prevents patients from receiving a potentially life-changing therapy. One of those psychiatrists was looking after Karen in December 2010, seven months after her first suicide attempt, and saw the possibility of an effective treatment when nothing else she had tried had helped.

A modern ECT session, says Prof George Kirov, a psychiatrist at Cardiff University's School of Medicine, goes like this: an anaesthetist inserts a thin tube in the back of the patient's hand and administers both muscle relaxants and a general anaesthetic, which puts the patient to sleep. An ECT nurse squeezes conductive gel onto a pair of electrodes and holds one to each of the patient's temples. Another member of the team then sets the level of the electrical current, and pushes a button. Current pulses briefly through the electrodes, eliciting a seizure that lasts between 15 and 40 seconds. Prof Rupert McShane, a consultant psychiatrist at Oxford Health NHS Foundation Trust, explains that the muscle relaxants keep the patient mostly still. "Usually you can see some muscle twitching, but we use an electroencephalogram [which monitors brain activity] to see that the patient is having a fit."

The procedure is surprisingly quick. The patient wakes up a couple of minutes after their seizure finishes, and they are taken to a supervised recovery room. When they feel up to moving, they are offered a drink and some food. They'll do this twice a week, for around six weeks.

After Karen's first session, in December 2010, she woke up to "the worst headache of my life", she says. Other patients report becoming confused and needing time to remember where they are. During the weeks of treatment, patients often experience memory loss; for the majority, this resolves itself in the months after treatment finishes.

After her fourth session, Karen went back to her ward and asked for a drink. This was a big deal for two reasons. Karen had lost any interest in eating or drinking over the preceding weeks – now she was doing it voluntarily. She had also chosen to speak to someone – another rarity. With each session she felt progressively better, and eventually started eating on her own. "It felt like there wasn't something heavy on me any more," she says. Karen stopped after nine sessions, and her psychiatrist discharged her a few weeks later, in February 2011.

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The number of ECT clinics that have closed in England, Wales, Ireland and Northern Ireland since 2009.

THE SCIENCE

What was going on in Karen's brain that made her feel better so quickly? No one knows, exactly. What we do know is that the seizure is key: the better the seizure – gauged by certain

"EARLY ECT DIDN'T USE MUSCLE RELAXANTS, SO IT PRODUCED VIOLENT SEIZURES"

ILLUSTRATION: EMMANUEL POLANCO

qualities on the EEG – the greater the improvement. Researchers have found several possible pathways that could be involved (see box, overleaf).

Karen's rapid response was not unusual, however. In 2004, results from one of the largest ever ECT studies were published in the *Journal Of Clinical Psychiatry*. The study looked at 253 patients with major depressive disorder, and found that three-quarters of them reached remission after receiving ECT. In this context, remission can mean that mute patients start speaking, or catatonic patients start moving. Suicidal thoughts might recede, and patients may begin to engage with long-term therapy. McShane says that, for people with severe depression, those rates of improvement are considerably better than for antidepressants. But ECT research isn't without controversy.

Clinical psychologist Dr John Read at the University of East London points out that no placebo-controlled study of ECT has been published since 1985, and those published before then were of "questionable methodological quality". Without trustworthy placebo-controlled studies, he says, any positive ECT results could simply be due to a placebo effect. In contrast, McShane says that the pre-1985 studies have already proved ECT's effectiveness, and cautions against repeating those studies: "It would be unethical to take a group of people with depression and treat half of the sample with an ineffective, sham treatment."

Read also has concerns that the effect of ECT doesn't last, and claims there has never been a long-term follow-up study in which ECT outperforms a placebo. And indeed, Kirov notes that in his clinic, and in others in the UK, about half of patients become unwell again within a year. This is even with the help of antidepressants, psychotherapy and what's called 'maintenance ECT', where the patient continues with ECT, but with decreasing frequency. Kirov says that relapse is ECT's biggest problem. "They get back into depression. Not necessarily to the same level, but they go back." And if relapse is the main problem with ECT, then side effects are certainly the second.

In 2011, the late actor Carrie Fisher wrote about her experience with ECT in her memoir *Shockaholic*. But her mostly positive account came with a caveat: "the truly negative thing about ECT is that it's incredibly hungry and the only thing it has a taste for is memory".

ECT interferes with memory, both anterograde (the laying down of new memories), and retrograde (recalling things from the past). Anterograde memory problems usually resolve themselves a few months after finishing treatment, but for some individuals – 13 to 55 per cent of people, depending on which study you read – retrograde memory loss can be permanent. Kirov says that for these people, continuing becomes a personal choice: "Some of them are disturbed by their memory problems and decide to stop." Karen experienced retrograde memory loss, though it has improved since finishing treatment. "I couldn't remember things, like what we did on holiday, and that was quite frustrating. But I didn't like being unwell, so there was a trade-off."

REPUTATION PROBLEMS

Historical scars also mar ECT's reputation: early applications didn't use muscle relaxants, so it produced violent seizures where patients occasionally broke bones. Ken Kesey's 1962

HOW DOES ECT WORK?

RESEARCHERS HAVE DISCOVERED SOME CHANGES IN THE BRAIN AFTER ECT, BUT HAVEN'T SETTLED ON ANY DEFINITIVE ANSWERS AROUND HOW IT WORKS. HERE ARE THE MAIN CONTENDERS...

HORMONES AND NEUROTRANSMITTERS IN THE BRAIN

ECT increases the levels of some neurotransmitters (chemical messengers that transmit signals between neurons) and hormones in the brain. Serotonin and dopamine are two neurotransmitters that increase after ECT. Serotonin regulates anxiety and reduces depression, while dopamine affects mood and motivation. Antidepressants have similar effects on the brain, but as ECT is generally faster acting and more effective than antidepressants, experts believe these changes cannot entirely account for ECT's benefits.

INCREASES IN THE SIZE OF THE BRAIN'S EMOTIONAL PROCESSING AREAS

A recent study in humans showed that ECT increases the amount of grey matter in the brain's hippocampus and the amygdala.

The hippocampus is involved in learning, memory and emotion, while the amygdala plays a role in the processing of emotions. However, this increase in volume of grey matter wasn't correlated to noticeable changes in the mood of the patients, so more research is needed to establish whether or not this is a contributing factor.

CHANGES IN BRAIN CONNECTIONS

One study has shown that patients with severe depression have more connections between certain brain regions, including the prefrontal lobes, than healthy controls. Experts suggest that these connections could account for the ruminations and hyper-alertness that characterise some forms of depression, so decreasing these connections might help a patient. According to several studies, after ECT there are fewer connections between prefrontal lobes and other areas of the brain. But ECT may also build new connections in some areas of the brain, so more research is needed.

"THERE IS A ROLE FOR ECT. BANNING IT WOULD BE LIKE REMOVING A LIFELINE"

book *One Flew Over The Cuckoo's Nest*, and the 1975 movie, depicted ECT as a form of behavioural control for psychiatric patients, perhaps an accurate portrayal of certain hospitals back in the 1950s. And in the 1980s, ECT was used as a 'treatment' for homosexuality. This practice didn't last, but it still remains etched in cultural memory.

The use of ECT is declining in the UK, according to the latest report by the ECT Accreditation Service. "Its portrayal in movies has been profoundly stigmatising, and has misrepresented current practice," says McShane. He argues that a lack of knowledge around severe depression means the costs and benefits of the treatment cannot be accurately weighed up. "That discussion often omits the severity of the illness. ECT causes side effects, but so does chemotherapy." He says that if the public were more aware of the reality of being severely mentally unwell, they might be more accepting of the treatment – "but those patients often don't want to talk".

Stigma can affect doctors as well as patients. According to Kirov, most psychiatrists who object to ECT haven't actually seen it used. To counter misinformation, he encourages every medical student to observe ECT. But he isn't sure what to do for the public. "It's hard to change public opinion. People have heard too many bad stories," he says.

To make matters worse, ECT has become a proxy for a long-argued question: is depression a medical problem, or a social one? Read, who's critical of ECT, argues the social side, saying that ECT is the most extreme example of the over-medicalisation of human distress: "It's not an appropriate response to a social problem." He calls for more work on population-wide wellness, and improved access to a range of psychological therapies and social support. McShane insists that ECT patients "are generally either too ill to make use of psychotherapy, or have already tried it without success".

BRIGHT FUTURE

In the end, Karen needed both ECT and psychotherapy. Her return to health was difficult. She relapsed a few months after her first course of ECT, falling back into severe depression. "I was reliving [the trauma] all the time. I started hearing him constantly talking to me, and I could feel him touching me." By February 2012 she was back in a psychiatric unit, sectioned after another suicide attempt. She spent a year and a half trying various other therapies, before starting her second round of ECT in August 2013. At that time, Karen was too unwell to give consent herself, but her family fought for her to receive it.

After three sessions, Karen became calmer. "I had lots of input from then on," she says. Karen was assigned a new psychologist, who guided her through psychotherapy during her ECT. She continued with the ECT, gradually reducing its frequency, until she was having just one session every three weeks. In September 2014, she was discharged, and in 2015 decided to stop ECT completely. "I'd got to a point with therapy where I was processing what had happened to me," she says. In 2016, after three years of therapy, Karen decided to stop that too. She doesn't regularly see doctors any more, and says that life is finally back to normal for her.

What would have happened if ECT wasn't an option? "I don't think I'd be here," she says. She cautions that while ECT certainly isn't for everyone, "there is a role for it. Banning it would be like removing a lifeline." **SF**

by **HELEN GLENNY**

Helen is a freelance science and travel journalist, with a background in neuroscience and physiology.

DISCOVER MORE

Watch short films and read articles about mental health from the BBC Three series Minds Matter. ***bit.ly/bbc_mind_matters***

If you have been affected by any issues raised in this article, there is help and advice available here: ***bit.ly/mental_health_support*** *If you are concerned about the mental health of you or a loved one, please visit your GP.*

ILLUSTRATION: EMMANUEL POLANCO

OVERPOPULATION
THE DEBATE

POPULATION WITH CHRIS PACKHAM

In this show, environmentalist Chris Packham asks whether we should be reducing our population to ease the strain on our planet's resources. Check *Radio Times* for details.

In richer countries around the world, people are grappling with the ethics of bringing children into a crowded and overheated planet. But is a reduction in birth rates the best way to beat climate change? The argument rages on...

by JOCELYN TIMPERLEY

Ecologist Emma Olliff doesn't want her own children. Not biological ones at least. She made the decision quite young, she says, but she only fully consolidated the reasons why in her early 20s.

"I did a marine biology degree, and then a biological diversity masters," she says. "And so was made very aware of human impacts on the environment, and how more of us is only going to make it worse."

She isn't alone. The idea of reducing the number of children you choose to have – or even going child-free – for environmental reasons has had a surge of interest in the past few years, with a particular focus on the climate impact of adding another person into the world. Some also say they are concerned about bringing children into a world with such an uncertain ecological future.

But not everyone is convinced about the merits of focusing on population as a solution to the world's environmental woes. Some people point to the dark history of enforced population control by political leaders or movements.

All this feeds into a debate on how much emphasis should be put on reducing the number of people on the planet to tackle climate change.

IN THE CROWD

Olliff is a board member for Population Matters, a UK charity that campaigns for people to have smaller families as a way to increase sustainability. And there are some influential environmentalists among the charity's patrons, including Sir David Attenborough, Jane Goodall and Chris Packham, which gives weight to the argument. Indeed, few people would dispute that there is *some* physical limit to how many people can live on Earth sustainably in the long time. There are currently 7.7 billion people on Earth, and this could rise to 9.7 billion by 2050 and 10.8 billion by 2100, according to UN projections. But the *actual* increase will depend hugely on what happens with policies, healthcare and culture over the next decades.

So how many people is too many? Trying to answer that is tricky. Even defining the term 'overpopulation' is hard. "Ask eight different people [and] you get eight different answers about what overpopulation means," says Raywat Deonandan, associate professor in global health at the University of Ottawa, and an expert in epidemiology. Deonandan himself retreats to the standard demographer definition of overpopulation: the point at which a population exceeds the land and ability to sustain it. But this opens up the question of what 'sustain' actually means. "Traditionally 'sustain' just meant 'keep you alive'," says Deonandan. "It's not really what we mean any more."

In climate terms, sustainability translates into the need to maintain a relatively stable climate, which a report from the International Panel on Climate Change (IPCC) last year showed means lowering emissions enough to keep global temperature rise to no more than 1.5°C.

Most of the carbon budget for this has already been used up, explains Kimberly Nicholas, associate professor in sustainability science from Lund University in Sweden. "So if we're going to avoid dangerous climate change, which I really hope that we do, we have to radically and rapidly reduce emissions that we have today. That's flying and driving and burning fossil fuels and raising livestock."

"THE PICTURE IS MUCH MORE COMPLICATED THAN 'FEWER PEOPLE MEANS LOWER EMISSIONS'"

PLANET OF TWO HALVES

The IPCC recognises population as one factor in greenhouse gas emissions. Its projections show that, if all else is equal, lower populations in the future will support lower emissions, and the most sustainable future scenario has a population lower than today's.

But the picture is much more complicated than 'fewer people means lower emissions' for one very clear reason: inequality.

The average greenhouse gas emissions emitted per person vary hugely from country to country. They sit at around 20 tonnes of CO_2 equivalent per year for each person living in the US, for example, but around two tonnes per year for Indian citizens. In the UK, they average seven tonnes per year. And this isn't even accounting for the many products made in Indian factories that are consumed in the UK and the US.

This means that where babies are born tends to influence their total climate impact significantly, with people born in high-consumption, rich countries far more likely to lead high-emitting lifestyles.

Another way of looking at emissions inequality comes down to wealth. An Indian businessman flying often by private jet will have far higher greenhouse gas emissions than other Indians on average; ➤

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while a British person living in food poverty is likely to have low emissions compared to their compatriots.

The poorest half of the global population is responsible for only around a one-tenth of global emissions attributed to individual consumption, according to a 2015 report from charity Oxfam. The richest 10 per cent globally, meanwhile, are responsible for around 50 per cent of the emissions, and have carbon footprints 60 times as high as the poorest 10 per cent.

CARBON CHILDREN

These stark figures show why the climate impact of population size simply cannot be thought about in a silo, according to Dr Katharine Wilkinson, co-author of *Drawdown*, a book which highlights the most effective solutions to tackle climate change.

"If we had just a billion people on Earth but people were wildly consuming fossil fuels and industrial agriculture was growing and people were eating beef five meals a day, you can imagine a scenario where the population's very small and actually the impact is still really significant," she says. "Similarly, if we have a large population but consumption comes way down then that's also a different scenario."

Those in the rich world who have decided to have fewer or no children for climate reasons often make this argument. "The impact of our children is considerably more than the impact of children in areas where the birth rate is so much higher," says Olliff. This argument is supported by an oft-cited scientific study published in the journal *Environmental Research Letters* in 2017. The study reviewed the available research on the actions that people in rich countries could take to reduce their climate impact.

"Basically we wanted to know, as an individual in an industrialised country, what can I do that really makes a difference for climate change, that would most reduce my carbon footprint," says Nicholas, who co-authored the study.

The study found that four choices were consistently high impact in cutting emissions: eating a plant-based diet, living car-free, avoiding flying and having one fewer child. The biggest impact choice of these? Having one fewer child, which would save 58.6 tonnes of carbon per year. The next most effective was living car-free for a year, which would save 2.4 tonnes. "That was basically showing every child that we would choose to create in a high-emitting country has a huge carbon legacy," says Nicholas.

Assigning responsibility to a parent for a child's emissions in this way is contentious. Some say a child's emissions aren't part of their parents' 'carbon footprint', while others note the risk of framing things in terms of 'too many people'. "There are certainly many deeply problematic and racist and xenophobic and horrible human rights violations that have happened, or been proposed, in the name of 'solving' overpopulation," says Nicholas.

"THERE ARE MANY HORRIBLE HUMAN RIGHTS VIOLATIONS THAT HAVE HAPPENED IN THE NAME OF 'SOLVING' OVERPOPULATION"

It also puts an emphasis on personal lifestyle choice, which some say comes at the expense of a focus on more systemic changes to tackle climate change. Effort should go instead to tackling the underlying issues of reliance on fossil fuels and overuse of resources, according to this perspective.

"I'm not a fan of burdening global care to the choices of individuals, who must often make personal choices against their personal self-interest," says Deonandan. "To me it makes more sense to create economic incentives and disincentives to guide populations into making more sustainable choices."

But others argue individual action can scale up to bigger changes. "I think you need individuals to feel engaged and empowered in their sphere of influence that what they can do actually makes a meaningful difference, to get enough people activated to actually solve the problem," argues Nicholas.

Still, as Wilkinson adds, the climate crisis will absolutely not be solved by individual behaviour change alone. "To the degree that people are thinking about individual behaviour change, I think it's really good to have a rigorous grounding for that," she says.

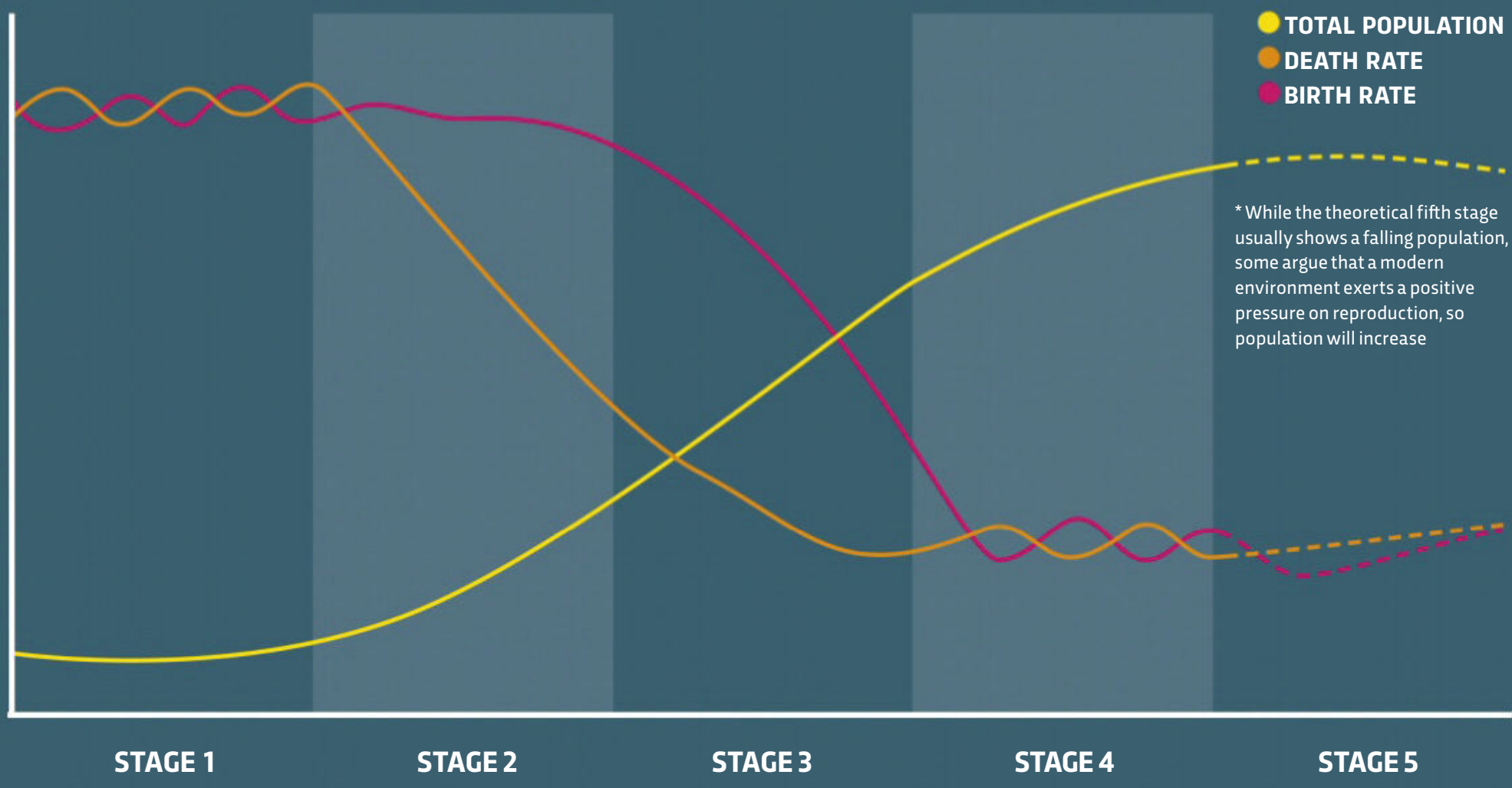
The average emissions per person remain highest in rich, industrialised countries like the US. But population growth has also tended to level off in these countries.

In poorer countries earlier along the 'demographic transition', such as India and much of Nigeria, rising populations and a growing middle class increasingly need – and, many argue, deserve – increasing resources. But if these economies develop in a high carbon way, this could lead to rising emissions.

This is why many see supporting people in poorer countries who want to have fewer children as key to reducing emissions globally. Educating girls and family planning are two of the most effective measures for tackling climate change, according to Project Drawdown. Research also shows that women and girls are particularly vulnerable to the effects of climate change because their roles as caregivers, and providers of food, fuel and water puts them particularly at risk if drought or flooding

THE DEMOGRAPHIC TRANSITION MODEL

This model is widely accepted in the social sciences to map the relationship beween fertility and development



In the first stage, there is a low population but a high birth rate, which is balanced by a high death rate. People are dying of famine, and there is a high child mortality rate. Life is short and harsh and there is a high incentive for having lots of children, because most are going to die. In the second stage, the death rate starts to decline due to improved health measures, such as better food, clean water and vaccination. Birth rates remain high and the population starts to rise. The third stage sees the birth rate start to drop due to social innovations such as educating girls, family planning and moving to cities. By the fourth stage, as seen in most of the Western world, there is a large population that is still growing slowly, with a low birth rate and a low death rate. The fifth stage is still theoretical, but shows a high population that starts to slowly fall, due to low birth rates and ageing.

Some countries, such as the UK, moved through the stages slowly. Others, like China, passed through the demographic transition model extremely quickly. However, the demographic transition is not inevitable, and requires investments, policies, education and support.

occurs. This increases the stakes for ensuring they are protected yet further.

"If you actually look at their impact together, educating girls and family planning, or as I prefer to talk about, closing the gaps on access to reproductive healthcare, then it actually turns out … to be the number one solution," says Wilkinson.

Access to good quality family planning is recognised by the UN as a human right and is known to benefit the health and welfare of women and their children. It also brings down fertility rates. Similarly, women with a higher education level tend to have fewer, healthier children and manage their own reproductive health more actively.

Education and reproductive healthcare are things that women and girls should have, says Wilkinson, noting that around the world there are still 132 million school-age girls not in school, and 214 million women who say they have unmet needs for contraception. "They [education and reproductive healthcare] happen to have these positive ripple effects when we start to add up the individual decisions that a woman or a family makes across the world, and over time start to have real impacts at scale," she says.

At the same time, it is crucial to avoid the dangerous and problematic territory where the reproductive choices of women are controlled or determined for them one way or the other, she adds.

Similarly, for those in richer countries who may be considering having fewer children due to climate change, the most important thing is that it is a personal decision. "It's got to be something you choose and you're happy to choose," says Olliff. "I'm just trying to raise awareness to make more people feel happy about choosing that decision." SF

by JOCELYN TIMPERLEY
(@jloistf)
Jocelyn is a freelance climate and science journalist.

Q&A

ALL YOUR QUESTIONS ANSWERED

THIS ISSUE'S EXPERTS

DR ALASTAIR GUNN
Astronomer, astrophysicist

ALEX FRANKLIN-CHEUNG
Environment/ climate expert

ALOM SHAHA
Science teacher, author

PROF ALICE GREGORY
Psychologist, sleep expert

DR HILARY GUITE
Former GP, science writer

CHARLOTTE CORNEY
Zoo director, conservationist

DR HELEN SCALES
Oceans expert, science writer

DR CHRISTIAN JARRETT
Neuroscientist, science writer

DR EMMA DAVIES
Chemistry expert, science writer

LUIS VILLAZON
Science/tech writer

JULES HOWARD
Zoologist, science writer

PROF ROBERT MATTHEWS
Physicist, science writer

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STEVE GRANTHAM, PRESTON

WHAT'S THE MOST DANGEROUS SPORT?

This is surprisingly hard to answer, as it depends both on how the risk is measured – per participant, say, or per event – and the availability of reliable data. But according to a 2014 analysis by Prof Sir David Spiegelhalter at Cambridge University, the UK's leading authority on risk, mountaineering is probably the most dangerous sport, carrying a risk of death of around 1 per cent per climb. By comparison, running a marathon is around 1,000 times safer. *RM*

NYE LEWIS-DAVIES

WHAT DOES THE WORLD LOOK LIKE OUTSIDE OF OUR BRAINS?

Your question has echoes of the American philosopher Thomas Nagel's classic paper "What is it like to be a bat?" – a creature that is able to navigate using echolocation (by bouncing sounds off the environment). Nagel wrote that we can never step outside of our own brain and take the bat's perspective on the world because we lack their sensory equipment. Likewise, one could argue that we can never know what the world 'looks like' free from our brains because we can only perceive objective reality through the veil of our senses, such as via wavelengths of light hitting our retina, or odorous molecules stimulating nerve cells in our nose.

We can't even ever truly know if the world looks the same from the perspective of another human brain. For instance, the colour that I label 'red' may subjectively look different to you than it does to me.

We know as a matter of fact that there are aspects of physical reality that we cannot detect ourselves – such as radio waves, ultraviolet light (detectable by birds and bees, among other creatures) and high-pitched ultrasound (used by bats). And of course, there are likely many other aspects of reality not yet detectable by any creature or our most advanced technology – a possibility that fuels the imagination of science fiction writers and mystics alike.

But while our take on the world is restricted by the limitations of our own neurological systems, it would be a mistake to underplay their potential. For starters, we have way more than five senses (among the other are balance, hunger and proprioception – the sense of where our body is in space). What's more, recent research suggests that it may be possible for us to learn a form of echolocation, by making clicks with our mouths. Indeed, some blind people can already do this, using the echoes to piece together their environment as a bat would. ***CJ***

MARTIN OGILVIE, NORWICH

WHERE DO SMELLS GO?

Smells 'disappear' when the aroma molecules disperse in the air to a concentration below your detection threshold. Your nose is more sensitive to some compounds than others: the eggy smell of hydrogen sulphide is detectable at concentrations of two parts per billion, while nail varnish remover (acetone) needs to be 50,000 times more concentrated before you can smell it. Some aroma molecules may also chemically react in the air to form a different compound that you are less sensitive to. *LV*

JULIUS CENTIK, PIEŠŤANY, SLOVAKIA

WHY DOES THE CLINKING SOUND GO DOWN IN PITCH WHEN I STIR SUGAR INTO MY COFFEE?

When adding sugar into coffee – or any hot drink – the 'clink' of the spoon striking the mug's sides becomes lower in pitch. The explanation is surprisingly subtle, and lies in the effect of the sugar on the liquid. The rough surface of the sugar granules traps molecules of air dissolved in the liquid, creating tiny bubbles. These make the liquid in the mug more 'squashable' – the technical term is 'compressible' – allowing it to mop up more of the energy in the sound waves created by the spoon, which in turn makes them travel more slowly through the liquid. As the speed of the sound waves in the mug is proportional to their frequency, the reduced speed lowers their frequency, which we hear as a drop in pitch. *RM*

DIY SCIENCE

HOMEMADE LAVA LAMP

WHAT YOU'LL NEED

- A tall, open container such as a plastic drinks bottle or a glass
- Cooking oil
- Water
- Food colouring
- Fizzy vitamin tablet or Alka-Seltzer

WHAT TO DO

1. Fill the container about a third of the way up with water.

2. Pour cooking oil on top of the water until the container is nearly full.

3. Wait for the oil and water to separate.

4. Add a few drops of food colouring and wait for the water to become coloured.

5. Break the tablet in half and drop it into the container.

6. Watch the lava lamp do its thing!

7. Add more pieces of the tablet to keep the reaction going.

WHAT'S HAPPENING

The key to how the 'lava lamp' works is the fact that oil and water don't mix. Whether two liquids mix depends on the interactions between their molecules and also their freedom to move around – the stronger the attractive forces, and the greater the possibilities of movement, the more likely they are to mix.

Water molecules are 'polar' – one end is negatively charged, and the other is positively charged. This means that water molecules attract each other more strongly than they attract oil molecules, which are 'non-polar'. Also, the water molecules end up forming a kind of cage around the oil molecules, restricting the motion of both. This is an unfavourable state, and the water and oil molecules quickly separate. The oil floats on top of the water because it is less dense.

The tablets contain citric acid and sodium bicarbonate, which are released into the water when the tablet dissolves. When particles of these two chemicals come into contact with each other, they react, producing carbon dioxide gas. The gas forms bubbles in the water. These are less dense than both the water and the oil, so float upwards, dragging along some of the coloured water. The bubbles burst once they reach the top of the oil, and the water falls back down. ***AS***

GETTY IMAGES X3 ILLUSTRATION: DAN BRIGHT

HIDDEN FIGURES

JANET LANE-CLAYPON

The science of epidemiology has saved the lives of millions by helping to reveal the causes of good and bad health. Using so-called cohort studies, researchers have made some crucial discoveries, showing the deadly link between smoking and cancer, for example, and the benefits of exercise for mental health. Yet the scientist who pioneered this type of study was forced to abandon research and died in obscurity – chiefly because she was a woman.

Born in Lincolnshire in 1877, Janet Lane-Claypon was a brilliant medical student who became fascinated by epidemiology. In 1912, she published a pioneering study of two groups – 'cohorts' – of babies, fed breast milk and cow's milk respectively. Using sophisticated techniques, she not only discovered the link between breastfeeding and better growth, but also ruled out other potential explanations, such as family income.

Lane-Claypon then developed so-called case-control studies, where a group of people with a disease are compared to a broadly similar group free of the disease. This allowed her to identify risk factors for breast cancer that are still recognised as important today. But in 1929 she married a civil servant and was forced to quit under official regulations. While others took up her brilliant work, Lane-Claypon herself remains unknown even to those using her techniques. *RM*

THEODORE BARKAS, ATHENS

WHY DO WE SWING OUR ARMS WHEN WE WALK?

Experts believe that the ancestors of modern humans began walking upright at least 3.6 million years ago. Yet the reason we move our arms out of sync with our legs has only recently been solved. For years, the answer was thought to be simply balance. Research published in 2010 by a team led by Dr Sjoerd Bruijn at the Free University, Netherlands confirmed this – but with a twist. Swinging our arms doesn't make us much more stable when walking normally – but it does help restore our balance if we suddenly lose our footing while walking over uneven ground. Earlier this year, Bruijn and colleagues also found another benefit: swinging our arms while walking is more energy efficient than keeping them still. While it takes energy to move our arms, this is more than compensated for by the reduced energy needed by the rest of the body to propel itself forward. ***RM***

JESS ROCHEFORT

WHAT WOULD HAPPEN IF ALL THE SALT IN THE OCEANS SUDDENLY DISAPPEARED?

A litre of seawater contains around 35g of dissolved salt, so desalinating the entire ocean would involve removing 45 million billion tonnes of salt. The sudden reduction in weight pressing on the seabed would probably trigger earthquakes and volcanoes around the globe. Because freshwater is less dense, the Arctic icecap would sink an extra 10cm into the water, creating the largest tidal wave the planet has ever seen along northern Europe, Russia and Canada. A few hours later, virtually all marine life would die as their cells swelled and ruptured due to osmosis (water molecules move towards areas of higher salt concentration). They would sink to the ocean floor, but their bodies wouldn't decompose, because all marine bacteria would be dead too. Marine algae are responsible for at least half of Earth's oxygen production, so there would be mass extinctions on land as well. Eventually, the oceans would resalinate because minerals are continually dissolved from the land by rivers and carried to the sea, but this would take tens of thousands of years. ***LV***

EXISTENTIAL FEAR OF THE MONTH...

I'M MORE BACTERIA THAN HUMAN

There are more bacterial cells in your body than human cells, but the ratio isn't as extreme as once thought. A 2016 study at the Weizmann Institute of Science in Israel found that our total cell count is 56 per cent bacteria (compared with earlier estimates of 90 per cent). And because bacteria are much smaller, their total mass is only about 200g. So by weight, we are more than 99.7 per cent human.

Even so, we shouldn't underestimate the contribution bacteria make to our body, nor feel threatened by it. Most of our 'human' cells contain structures called mitochondria, which we rely on to convert glucose into compounds we can use for energy. These mitochondria probably began as free-living bacteria before they embarked on a symbiotic relationship with us. The only reason that we don't include them in our tally of bacteria is that they never leave the confines of human cell membranes, though they are, in many respects, independent organisms with their own DNA.

Like all multicellular animals, we can't easily point to individual components and say "This is part of me, and this is not". Your body is like a city – it has a collective identity that goes beyond its individual inhabitants. The pigeons and squirrels that call London home are just as much a part of it as the humans who live there. ***LV***

GETTY IMAGES X3, SCIENCE PHOTO LIBRARY ILLUSTRATION: DAN BRIGHT

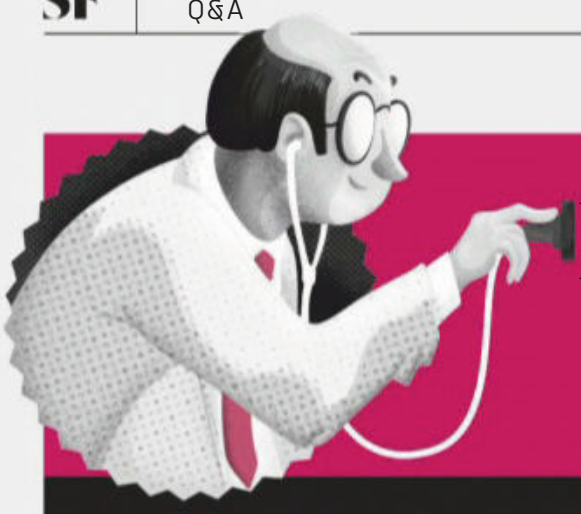
JUNO SANDFORD (AGED 5), HACKNEY

DO GIRAFFES MAKE A NOISE?

Although not the most talkative of animals, giraffes are known to snort or hiss when threatened, and female giraffes bellow to their young. But we recently discovered that they make other noises, too. In 2015, researchers analysed recordings of giraffes from zoos in Berlin, Copenhagen and Vienna, and found that they make low-frequency humming noises at night. It's thought that these otherworldly sounds are a form of 'contact call' between individuals who have been separated from their herd, helping them to find each other in the dark. Rather charmingly, another theory suggests that the humming is actually giraffes snoring or sleep-talking! ***CC***

526

The number of abnormal 'teeth' removed from the mouth of a seven-year-old boy in India. The teeth, which were found inside a growth in the lower jaw, ranged in size from 0.1mm to 3mm, and each had enamel, a crown and a small root.



DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I TOOK ONE OF MY WIFE'S CONTRACEPTIVE PILLS AS A DARE, BUT NOW I'M WORRIED. WILL ANYTHING HAPPEN?

Nothing will happen if you only took one. There's a one in four chance that the pill was a dummy anyway, as most packets include seven tablets with no drugs in them (meant to maintain the habit of taking the pill while the 'withdrawal bleed' happens). If you regularly took the 'combined pill', which contains oestrogen and progestogen hormones, it would have mild feminising effects, such as wider hips, softer skin and slight breast development. The oestrogen dose is about a tenth of that taken by transgender women, but it's a form of oestrogen associated with higher risks of deep vein thrombosis, so it wouldn't be a good idea for anyone wanting to transition. Regularly taking a progestogen-only pill would have the main impact of reducing your sperm count and libido. ***HG***

DO I REALLY NEED TO LEAVE MY FOOD TO STAND AFTER IT COMES OUT OF THE MICROWAVE?

Microwaves only penetrate to a depth of around three or four centimetres, so anything deeper is heated indirectly, by conduction from the outer layers of food. The cooking instructions on a ready meal might say to heat it on full power for five minutes and then leave to stand for another two. The first phase adds enough energy to cook your lasagne, but when it comes out of the microwave, that energy is unevenly distributed. Leaving it to stand allows the heat to make it to the centre, where it will kill off any bacteria. So always respect the instructions. ***LV***

WHY DOES NO ONE AT WORK CARE ABOUT MY LOVELY SUMMER HOLIDAY?

It may seem that way, but rest assured, it's probably not that they don't care, and it's probably not all down to jealousy, either. It's likely that they just find it difficult to fully appreciate what an awesome time you had.

Psychologists at Harvard University have been studying the social dynamics that play out when we share stories. They've found that most of us (storytellers and listeners alike) think that it will be more pleasurable for all involved to hear stories of extraordinary experiences rather than more mundane tales. Yet the converse tends to be true – it's actually more rewarding to share stories that everyone finds familiar. A key reason is that it's such a challenge to convey exciting or unusual experiences in words. Your head may be filled with memories of astonishing views or hilarious nights out, but unless you're a gifted raconteur, when you try to articulate those experiences, your audience is likely to be left cold. So, paradoxically, the more remarkable your summer escape, the more you risk alienating your audience. By contrast, if you went somewhere familiar and did what many others in your social group do, your colleagues will probably enjoy hearing about your holiday more, as they'll be able to chip in with their own anecdotes. ***CJ***

DAVID KELLY, MANCHESTER

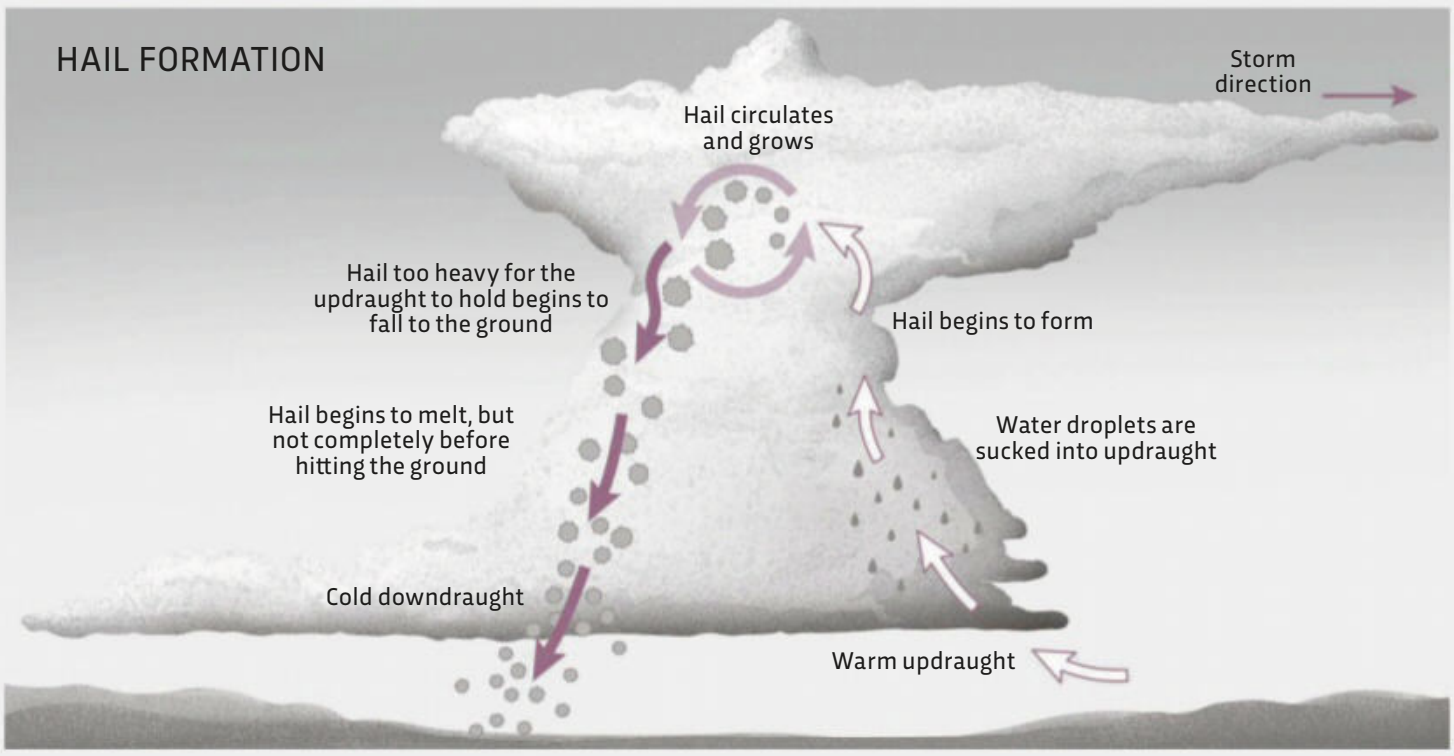
DO OBJECTS IN THE UNIVERSE MOVING TOWARDS US SHOW A BLUE SHIFT?

The wavelength of light emitted by an object is changed by its motion relative to an observer. An object moving away from us is 'redshifted' – that is, its light is shifted towards the longer wavelengths at the red end of the visible spectrum. But although the Universe is expanding, not all objects are redshifted. Some of the nearest stars, such as Barnard's Star, are moving towards us and hence show a 'blueshift' (their light is shifted towards shorter wavelengths). Even some galaxies (for example, the Andromeda Galaxy) are blueshifted. This is because, over relatively short distances, the local gravitational attraction between galaxies can overcome the general expansion of the Universe. The highest blueshift yet recorded is actually from a group of stars called a 'globular cluster' that's whizzing towards us at 1,026km/s. But fear not – it is still millions of light-years away! ***AGu***

JOYCE BURLEY, HULL

WHY DOES TOOTHPASTE CONTAIN SWEETENERS?

Toothpaste needs something to mask the soapy taste of the detergents that create the foam when you brush. Sugar is out, for obvious reasons, but sweeteners such as xylitol or sorbitol do a pretty good job. These chemicals attract water molecules, so they have the added benefit of keeping water locked in the toothpaste, preventing it from drying out. Research also suggests that xylitol can help to kill off plaque bacteria in the mouth by starving them of sugar. ***ED***



DAVE FERRIS, LONDON

WHY DON'T HAILSTORMS LAST AS LONG AS RAINSTORMS?

Hail is produced during thunderstorms, when an updraught of warm, moist air carries tiny droplets of water upwards. The droplets freeze at high altitude, and the resulting ice crystals grow until they are too heavy to stay suspended. For hail to form, a warm air mass has to meet a much colder one (this is what creates the updraught). The hail only forms in a narrow region where these two air masses meet, meaning that it falls over just a small strip of land. These high-energy storms also tend to move quickly, so someone on the ground experiences the hail as a short burst. Finally, as they need a supply of warm, moist air to fuel them, hailstorms relatively quickly run out of energy and dissipate. ***AFC***

NATURE'S WEIRDEST CREATURES...

THE PINK FROGMOUTH

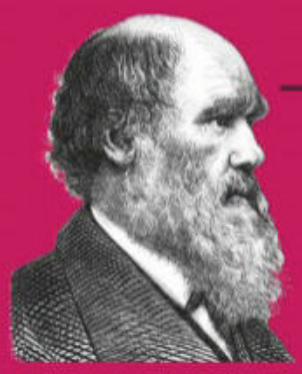
Hold onto your breath, dear readers, for this month we're diving deep. Hundreds of metres beneath the surface of the world's oceans, there lives a curious fish that waddles along the seafloor using its fins like four little legs. It has a pink complexion and a frog-like mouth. Upon its head is a unicorn-like dorsal fin which glows in the dark and entices inquisitive fish to their doom. This is the pink frogmouth, a deep-sea creature that looks to have been designed by a sugar-addled six-year-old.

Still holding your breath? Good. You and the pink frogmouth have this in common. Earlier this year, scientists discovered that this fish (and other members of its taxonomic family) has the unique ability of holding its breath underwater, for as long as four minutes.

Fish breathe by swallowing oxygen-containing water and pumping it through their gills, where the oxygen is extracted. The pink frogmouth, however, is able to hold this water in its gill chambers without exhaling. Puffed-up like this, its body volume can increase by as much as 30 per cent. There are a couple of possible reasons for this unusual behaviour: it could be a way of saving energy in an environment that's lacking in prey, and it could also help to ward off predators, similar to the pufferfish's defence mechanism. *JH*

GETTY IMAGES X2, ALAMY ILLUSTRATIONS: DAN BRIGHT

WHAT CONNECTS CHARLES DARWIN AND CHEWBACCA?

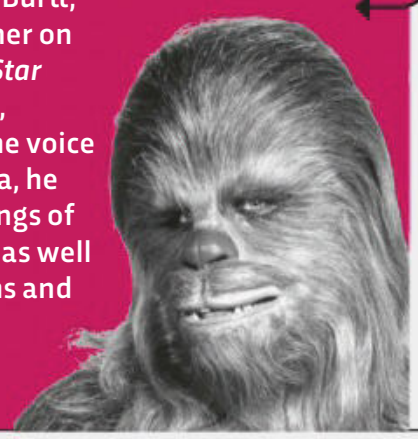


1. Although most famous for his work on evolution, Charles Darwin's final scientific book was about earthworms. It sold more quickly in its first year than *On The Origin Of Species*!

2. Earthworms are the staple food of badgers, making up to 80 per cent of their diet. Earthworms aren't very nutritious, though, so a single badger can eat several hundred of them in a night.

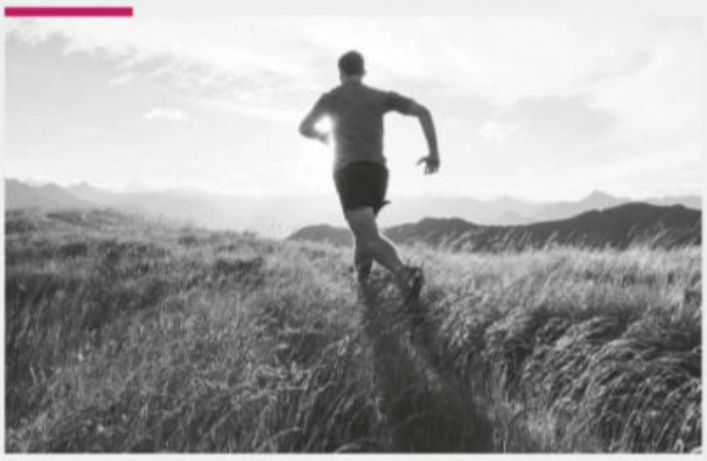
3. Badgers have a complex vocal repertoire of at least 16 different calls, ranging from low growls and grunts, to chitters, squeaks, yelps and even a sort of quacking sound.

4. When Ben Burtt, sound designer on the original *Star Wars* movies, developed the voice of Chewbacca, he used recordings of badger calls, as well as bears, lions and a walrus.



IAIN TODD, BRISTOL

WHY DO I PRODUCE SO MUCH SALIVA WHEN I GO FOR A RUN?



The various studies that have looked at this actually show conflicting results. It seems that a short jog in cold weather results in more saliva, while a marathon on a warm day actually reduces saliva production. Your body may initially be trying to offset the drying effect of the extra mouth breathing, but over longer periods dehydration sets in and your body reduces saliva production to conserve water. All exercise, regardless of the intensity, also makes you secrete more of a protein called MUC5B. This makes your saliva more sticky and viscous, which contributes to that dry mouth feeling you can get after exercising. ***LV***

ABBY SMITH, BIRMINGHAM

WHY SHOULDN'T YOU PUT TOMATOES IN THE FRIDGE?

Tomatoes from the fridge rarely fail to disappoint. Refrigeration does extend their shelf life by slowing the ripening process, but it also dramatically reduces levels of flavour and fragrance chemicals known as 'volatiles'.

A 2016 US study found that chilling tomatoes for a week reduced the activity of genes that code for enzymes needed to synthesise these volatiles, which are responsible for giving tomatoes a sweeter, more complex taste. ***ED***

STEPHEN NEWMAN, FOLEY, ALABAMA

HOW FAR DO WE TRAVEL THROUGH SPACE EVERY DAY?

This apparently simple question impinges on a fundamental axiom of physics: that there is no universal reference frame. So, when talking about the motion of the Earth, we have to declare which object the motion is with respect to. For example, at the Earth's equator you travel approximately 40,000km a day with respect to the Earth's centre. Each day, the Earth's orbit takes you about 2.5 million kilometres with respect to the Sun's centre. And each day, the Earth moves about 19 million kilometres with respect to the centre of the Milky Way. Finally, the Earth is also travelling about 47 million kilometres per day with respect to the 'cosmic microwave background' (CMB) – the leftover radiation from the birth of the Universe – which is perhaps the best surrogate we have for a universal reference frame. Since the directions of all these velocities are always changing, it would be meaningless to add them together. ***AGu***

GETTY IMAGES X8, ALAMY ILLUSTRATIONS: DAN BRIGHT

JED FITZHARRIS and ADAM TEMPEST

DOES THE CARBON DIOXIDE RELEASED FROM FIZZY DRINKS AFFECT THE ATMOSPHERE?

Fizzy drinks do release carbon dioxide (CO_2), but this pales in comparison with overall human CO_2 emissions. A can of pop contains 2-3g of CO_2 – a tiny proportion of the six tonnes of CO_2 per year (or 17kg per day) that the average person in the UK is responsible for. What's more, the CO_2 pumped into carbonated drinks is usually a by-product from power plants – meaning it would have been released into the atmosphere anyway. ***AFC***

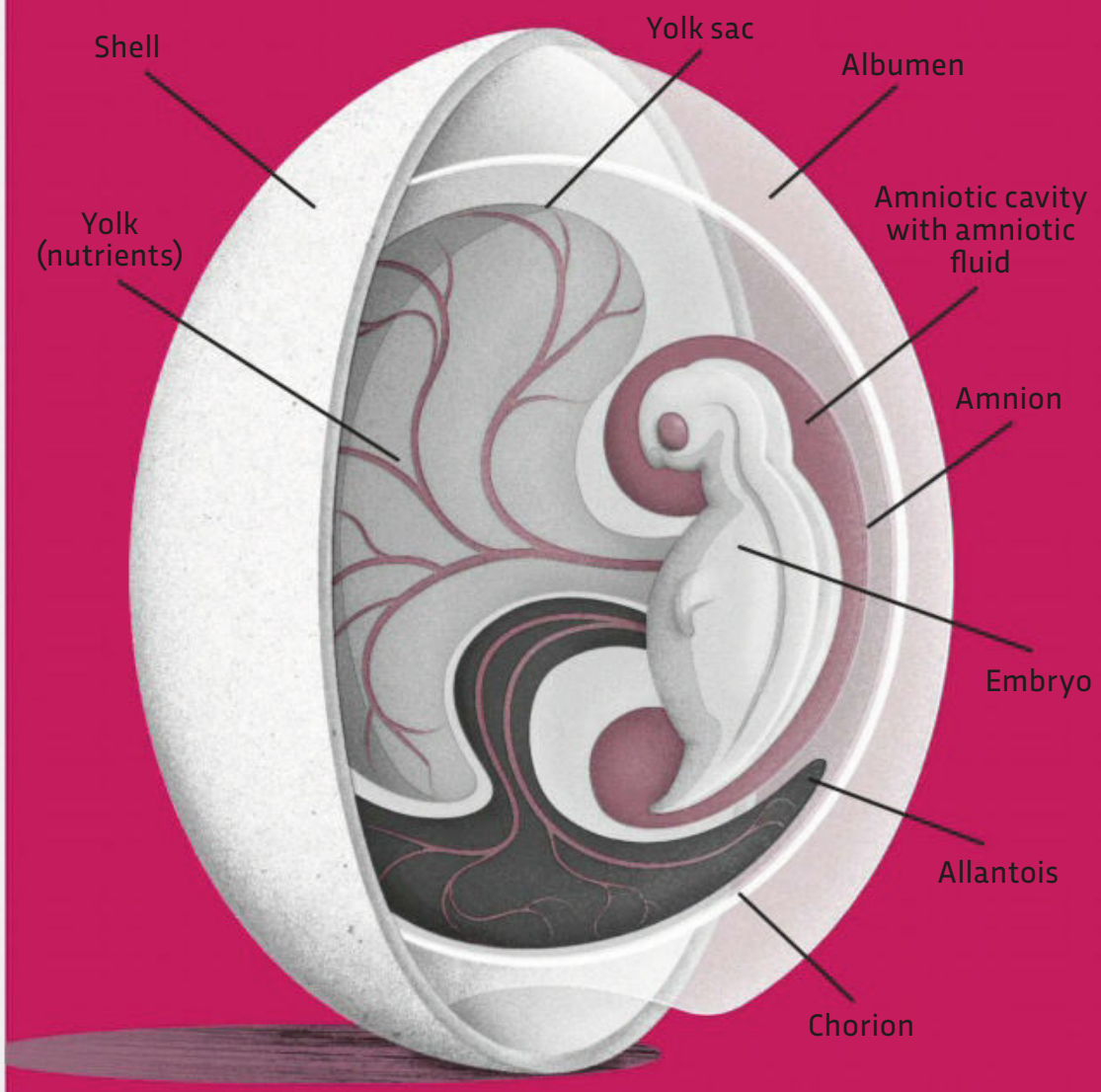
So shiny, even without an application of Pledge (other polishes are available)

REBECCA WALKER

WHY DO SOME INSECTS LOOK METALLIC?

Many insects, particularly scarab and jewel beetles, have vivid, metallic green, blue or gold colouration. This effect doesn't come from pigments, but is an example of 'structural colouration'. Microscopic ridges and transparent layers on the surface of a beetle's carapace act as an array of lenses that direct different wavelengths of light in such a way that some colours cancel out and others are amplified – the rainbow effect on a DVD is similarly caused by the microscopic pits on its surface. This metallic sheen may have evolved because it offers bright colours that can serve as a mating signal over long distances. Alternatively, some researchers have suggested that it might mimic the appearance of raindrops on leaves, helping to camouflage the beetles. The ridges and layers may also take less energy to grow than metabolically expensive pigment molecules – particularly important for insects because they regularly shed and regrow their outer skin. ***LV***

QUESTION OF THE MONTH



ELEANOR TEW, YORK

HOW DO BABY BIRDS BREATHE INSIDE THEIR EGGS?

It's all down to some nifty engineering inside the eggshell. Early on in a chick's development, it grows a hollow, sac-like structure from its gut, known as an 'allantois'. This pouch fuses with a second membrane ('chorion') surrounding the chick and its yolk, which together form the 'chorioallantoic membrane'. With one end attached to the chick, and one end close to the eggshell's inner surface, this membrane effectively acts like lung tissue, connecting the chick's circulatory system to the outside world. Oxygen diffuses through microscopic pores in the shell to the blood vessels in the chorioallantoic membrane, and then on to the chick's bloodstream. Carbon dioxide, the gaseous waste product of respiration, passes in the opposite direction. *CC*

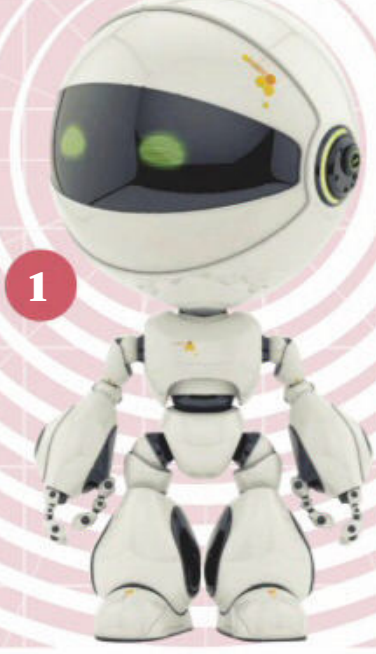
WINNER

Eleanor wins an Airbus 24hr watch, worth £115. The dial is split into two parts: day (light, upper part) and night (dark, bottom part) to logically follow the natural course of a day. According to Airbus, flight crew find it useful to help manage jetlag – perfect for your holidays!
flightstore.co.uk

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH



1. Celebrate science
This year the British Science Festival will take place in Coventry and Warwickshire and includes a programme of over 100 free events, including an address from Prof Alice Roberts.
10–13 September
britishsciencefestival.org

2. Game on the go
The dedicated handheld version of Nintendo's popular Switch console is released this month. With fixed controllers, the Lite only supports games with a handheld mode – but at £200, it is at least £80 cheaper than its more diverse sibling.
bit.ly/switch_lite

3. All about us
Wellcome's new permanent exhibition, *Being Human*, opens on 5 September. The display looks at our place in the 21st Century, what it means to be human, and our interactions with the world around us.
wellcomecollection.org

4. Too many people?
In his newest show for the BBC, Chris Packham looks at population growth. He asks: for the sake of the planet and our own survival, is it time we stopped reproducing?
Population With Chris Packham, BBC Two
Airs in October

5. Planetary party
Space Rocks is a day-long festival celebrating our Solar System and beyond, followed by a space-inspired live music set. Attending the event will be astronaut Tim Peake, rocket scientist Kate Underhill, and more.
21 September
spacerocksofficial.com

6. Worry not
The *ON EDGE* exhibit and accompanying events programme brings scientists and artists together to explore anxiety in today's society and consider the future of our mental health.
From 19 September
london.sciencegallery.com

JAMES COHAN, BBC, GETTY IMAGES X2

The front part of your brain, where higher thinking happens, doesn't finish developing until your **mid-20s** p90

2,900

The number of calories burnt in one day by online assistant Sara's black lab, as tracked by the PitPat2 monitor p95

Profile

A TIME OF CHANGE

IN HIS NEW BOOK ABOUT REVERSE PARENTING, DEAN BURNETT HELPS TEENAGERS TO NAVIGATE THEIR RELATIONSHIP WITH THEIR PARENTS. HERE, HE CHATS TO US ABOUT THE ADOLESCENT BRAIN

WHO IS THIS BOOK IS FOR?

Ostensibly and officially, it's for 11- to 16-year-olds who are finding that they are having a bit more of a tricky time with their parents than they used to. It's common: your parents have been the bedrock of your life and suddenly you find yourself arguing with them a lot more. But, unlike pretty much every other book which addresses this subject, my book is an explanation for the child or teen.

I certainly found it quite cathartic to understand why that was happening, so unofficially, I think the book is for anyone who's been a teenager.

WHAT INSPIRED YOU TO WRITE THIS GUIDE?

Well, I could give you some spiel about the 'sign of the times' and the intergenerational disputes, the strong political divide. Take the environmental aspect: Greta Thunberg is the leading voice of climate change, she's only 16. Right now, we're at a very, very important point in history where the older and the younger generation are perhaps more distant from each other than they've ever been. Something which addresses that, or at least helps people to understand it, could be helpful, and I think it is an important thing to consider right now.

But if I'm being completely honest, it was my editor Jamie who first approached me, and said: "I've got this idea for a reverse parenting book. Would you like to write it?"

I thought, yes, yes I would, and that's pretty much what happened.

"The things that affect you as a teen will stay with you for the longest time, the rest of your life. Particularly music, apparently"

WHY YOUR PARENTS ARE DRIVING YOU UP THE WALL
BY DEAN BURNETT
(£8.99, PENGUIN)

WHAT IS DIFFERENT ABOUT THE TEENAGE BRAIN, COMPARED TO THE ADULT BRAIN?

Loads of things. The adolescent phase of brain development is a distinct phase all by itself, though exactly when you start being an adult is a very fluctuating point, which no one seems to really agree on. When you're a child, you're absorbing everything. Some estimates say that in the first few years of your life, your brain is forming a million new connections every second, which is an incredible amount of data gathering and absorption. That carries on until we hit adolescence, though not at that phenomenal rate. Then, the brain sort of stops, takes stock, and says, right, we've got all this information. How much of this do we actually need?

It's like getting a brand-new smartphone. You're so excited, you fill it up with every single app, meme and download you can get your hands on. It's fun for a while, but eventually, that phone's going to become pretty useless. You'll try to find something basic like the calculator, and have to scroll through 50 pages of apps. With so much information in the brain, it's all about efficiency. Adolescence is when the brain starts becoming more efficient. It clears away the junk you don't need. There's a process called pruning, where lots of synapses that have never been used more than once are sort of just flushed away, and the resources for them are taken elsewhere.

WHY ARE TEENS SO EMOTIONAL?

There are some estimates that the front part of your brain, where all that higher thinking happens, doesn't finish developing until your mid-20s. The more central parts of the brain are older and more fundamental – which control things like emotions and impulses and risk-taking – they take less time to mature, so they're as efficient as possible in your early teens.

So, adolescents have this period where they can control their emotions, but it's a lot harder for them to do so, and the emotional experiences are far more intense as a result. Their emotions are harder to suppress, control or just keep under wraps. But they're constantly told to do just that. "Stop acting out. Stop being dramatic. Behave yourself; you're being stupid. You're being ridiculous."

This is the time when they're supposed to learn how to do all that stuff. If you suppress their emotions, if you make them keep quiet and sit still and never do anything, the brain never develops that ability, and it does cause serious problems down the line.

HOW MUCH OF OUR PERSONALITY IS SET DURING OUR TEENAGE YEARS?

The things you learn in your teens will stick with you for a long time, that's when you're undergoing substantial development. A lot of your baselines are established there too, like what your sexual preferences are, because you're flooded with these hormones giving you strange new feelings you've never had before, and strange longings that you can't quite get your head around.

There are some studies that show that because your teens are when your emotions are most powerful, the things that affect you as a teen will stay with you for the longest time, the rest of your life. Particularly music, apparently. That's why so many people think "music is rubbish; it was much better when I was young", that's because when you're a teen, things like music hit you at an emotional level far more profoundly than they do as an adult. Because the adult brain is more mature and more set, nothing else will really hit that same level of intoxication or emotional stimulation as it does when you're a teen. I'd say in 50 years' time there will be music journalists saying, "Oh, the 2010s, that was the year for music – we had *Mambo No. 5*, you don't have that."

[Actually, *Mambo No. 5* was released in 1999. And we're pretty optimistic no one was emotionally stimulated by it.]

DEAN BURNETT

Dean is a neuroscientist and full-time author. His latest book, Why Your Parents Are Driving You Up The Wall And What To Do About It, *is out now.*

Interviewed by* BBC Science Focus *editorial assistant Amy Barrett.

DISCOVER MORE

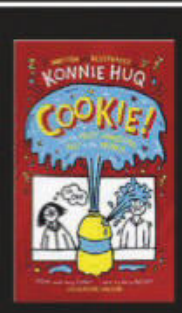
You can listen to our full interview with Dean in an upcoming episode of the Science Focus podcast ***sciencefocus.com/science-focus-podcast***

GETTY IMAGES

Author's bookshelf

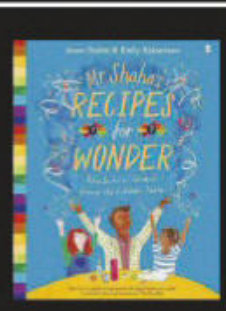
INVENTING OURSELVES
SARAH-JAYNE BLAKEMORE
(£8.99, BLACK SWAN)

An engaging and informative overview of the processes happening in the brain during teenage development, written by one of the leaders in the field.



COOKIE AND THE MOST ANNOYING BOY IN THE WORLD
KONNIE HUQ
(£10.99, PICCADILLY PRESS)

Konnie's new book for 8- to 12-year-olds is all about a determined girl with a passion for science and her dealings with the many problems life's thrown at her.



MR SHAHA'S RECIPES FOR WONDER
ALOM SHAHA AND EMILY ROBERTSON
(£8.99, SCRIBE)

A brilliant and beautifully illustrated book that allows parents and children to explore the fun side of science in their own home.

GET SMART

HUGH'S PICK OF SMART HOME SECURITY GADGETS SHOULD HELP KEEP YOUR BELONGINGS SAFE

GOOGLE NEST CAM IQ INDOOR

Google's indoor smart home camera comes in a cheaper model, but the IQ is superior in that it's smart enough to tell the difference between general motion and people. There's two-way audio so you can scare off burglars, and a 4K sensor for a sharp picture. Pay a bit more for a Nest Aware subscription and it will even recognise faces.

£299, STORE.GOOGLE.COM

SAMSUNG SMARTTHINGS

Samsung's smart home platform has come on leaps and bounds, with new devices being added all the time. Better yet is the wide-ranging support for other companies' cameras, doorbells and more that can play nicely with your SmartThings system. My top accessory is the Multipurpose Sensor, which monitors doors, windows and even temperature. Just remember you need the SmartThings Hub to run it all.

£79 (HUB ONLY), SAMSUNG.CO.UK

RING VIDEO DOORBELL 2

Ring has the best smart doorbell, in my opinion. My favourite feature is the rechargeable battery, so you don't have to wire it into the wall (although you can if you'd prefer), along with the ability to see and talk to any visitors through the mobile app. There's motion detection too and, handily, infrared night vision.

£179, EN-UK.RING.COM

ARLO PRO 2

As far as smart security cameras go, the Arlo Pro 2 is hard to beat for indoor and outdoor use. It's wireless and weatherproof, and offers crisp 1080p HD video along with zone detection (for highlighting specific areas) and two-way audio for yelling at any chancing intruders. Although the upfront cost is high, there's ample free storage. Works with Apple HomeKit, too.

£569.99 (FOR TWO CAMERAS), ARLO.COM

SIMPLISAFE

The clue is in the name: SimpliSafe's security system is a breeze to install and use. There's a heap of different bundles to choose from, or you can build a custom package from scratch, starting with cameras and moving up to panic buttons and glass-break sensors. Professional monitoring costs a monthly fee, but SimpliSafe still works as a local alarm without it.

£279 (FOR THE STARTER), SIMPLISAFE.CO.UK

Troubleshoot

SMART HOME SECURITY

IF YOU'RE GOING ON HOLIDAY, OR ARE JUST OUT AT WORK ALL DAY, YOU MIGHT BE TEMPTED TO BUY SOME SMART HOME SECURITY. TECH EXPERT HUGH LANGLEY GIVES US THE LOWDOWN

WHY WOULD I WANT A 'SMART' SECURITY SYSTEM?

Home security no longer means slapping a big, ugly box to the side of your house, nor does it demand an expensive professional to hardwire your new system in place. The smart home has ushered in a DIY security revolution: you can now build a decent security system in less than 30 minutes, with your smartphone acting as the controller. Smart home security systems beat traditional ones not just by eliminating hefty installation fees and long-term contracts, but in sheer convenience too.

WHAT DO I NEED TO GET STARTED?

Smart home security encompasses a wide range of gadgets, from cameras to doorbells, sensors to smoke alarms – but don't let it overwhelm you. Sure, maybe you want the full Fort Knox, but for the humble homestead a couple of indoor cameras and sensors can do the trick. Most smart home systems revolve around a hub, which connects to your Wi-Fi and talks to all the other 'smart' devices around the house. Cameras and motion sensors are the most common of these, but you can also add water leak sensors, smoke detectors and glass-breaking sensors.

WHAT'S SO SMART ABOUT THEM?

Smart systems give you more insight into what's happening than traditional systems, including notifications on your phone when sensors are triggered, and video clips of any suspect activity taking place. Using your phone you can arm/disarm the system remotely, and, if you have any smart locks, lock your doors with the tap of an app. Some smart locks even let you create 'virtual keys' so friends and family can enter the home when you're not there, while cameras and doorbells can be trained to recognise familiar faces and let you know who's knocking.

SHOULD I BUY A PACKAGE SYSTEM?

It depends on your setup. Companies like SimpliSafe offer comprehensive systems made of a central hub and a few sensors, with the option to add cameras, key fobs and sirens as desired. If you're not sure how many devices you need, look out for 'starter kits'. These serve as a great jumping-off point, and are often better value than buying individual devices. And while most smart security systems are designed to keep drill usage and cable-running to a minimum, some do offer professional installation should you still want it.

WHAT IF I RENT OR LIVE IN A FLAT?

Smart home companies are gradually adapting to renters and flat-dwellers. Still, you'll hit some limitations. For example, an outdoor camera might not be an option in a shared building, and you'll want to check with your landlord before chopping off the deadbolt for something smarter. Luckily, some security systems work great for flats too, as do many of the indoor cameras and sensors you can pick up individually. We're even starting to see smart doorbells that are perfectly designed for apartment living.

"Some smart locks let you create 'virtual keys' so friends can enter the home when you're not there"

HOW IMPORTANT ARE HOMEKIT, ALEXA AND GOOGLE ASSISTANT?

This matters more if you're buying devices piece by piece, as you'll want a certain amount of interoperability to keep things running and reduce the number of apps. My advice is to choose the system that best works for your home, and worry about the rest later. Luckily, many major systems support both assistants anyway. If you're a die-hard Apple user, you can build a decent security system around its HomeKit platform, thanks to a growing number of individual devices that play nicely.

ARE THERE A LOT OF ONGOING FEES?

There can be. Most systems offer a level of service for free, but some will require monthly payments to let you store video footage in the cloud or access special features like person detection. You don't need all the bells and whistles, but you should consider paying for professional monitoring if your system supports it, so you can dispatch the authorities if needed. Paying for cellular backup is also worth it, in case your Wi-Fi goes down.

HUGH LANGLEY *(@HughLangley)*
Hugh is editor at The Ambient, *which is dedicated to demystifying smart homes, and* Wareable, *which covers wearable technology.*

RECOMMENDED

FIND OUT WHAT'S CAUGHT OUR ATTENTION THIS MONTH

WHAT I'M WATCHING

Amy Barrett

EDITORIAL ASSISTANT

HORIZON: CANNABIS – MIRACLE MEDICINE OR DANGEROUS DRUG?

ON IPLAYER

Cannabis. One of the world's oldest and most controversial drugs. Even the word can conjure up that unmistakable whiff.

Components of cannabis include tetrahydrocannabinol (THC), which is responsible for the high, and cannabidiol (CBD), a non-psychoactive ingredient that's available as an oil in most pharmacies and health food shops. But what does scientific research say about the effects of cannabis on our brains and our bodies?

In this *Horizon* programme, A&E doctor Javid Abdelmoneim joins a research group hoping to find an answer. Over a number of weeks, Javid inhales – supervised, of course – different quantities of THC and CBD. Sometimes, he is relaxed and good-humoured; other times, he becomes anxious, paranoid and distrusting.

Travelling across the globe, to countries where medicinal cannabis has been used for decades, Javid meets patients whose lives have been turned around by the drug. And back in the UK, he is introduced to Alfie Dingley. Last year, seven-year-old Alfie received the first prescription of cannabis oil in the country to treat his rare form of epilepsy.

For Alfie and other patients, medicinal cannabis has clearly had a positive effect on their lives. But, Javid concludes, more research is needed before it can be deemed safe and prescribed routinely to people.

WHAT I'M READING

Alexander McNamara

ONLINE EDITOR

THE FUTURE STARTS HERE

BY JOHN HIGGS

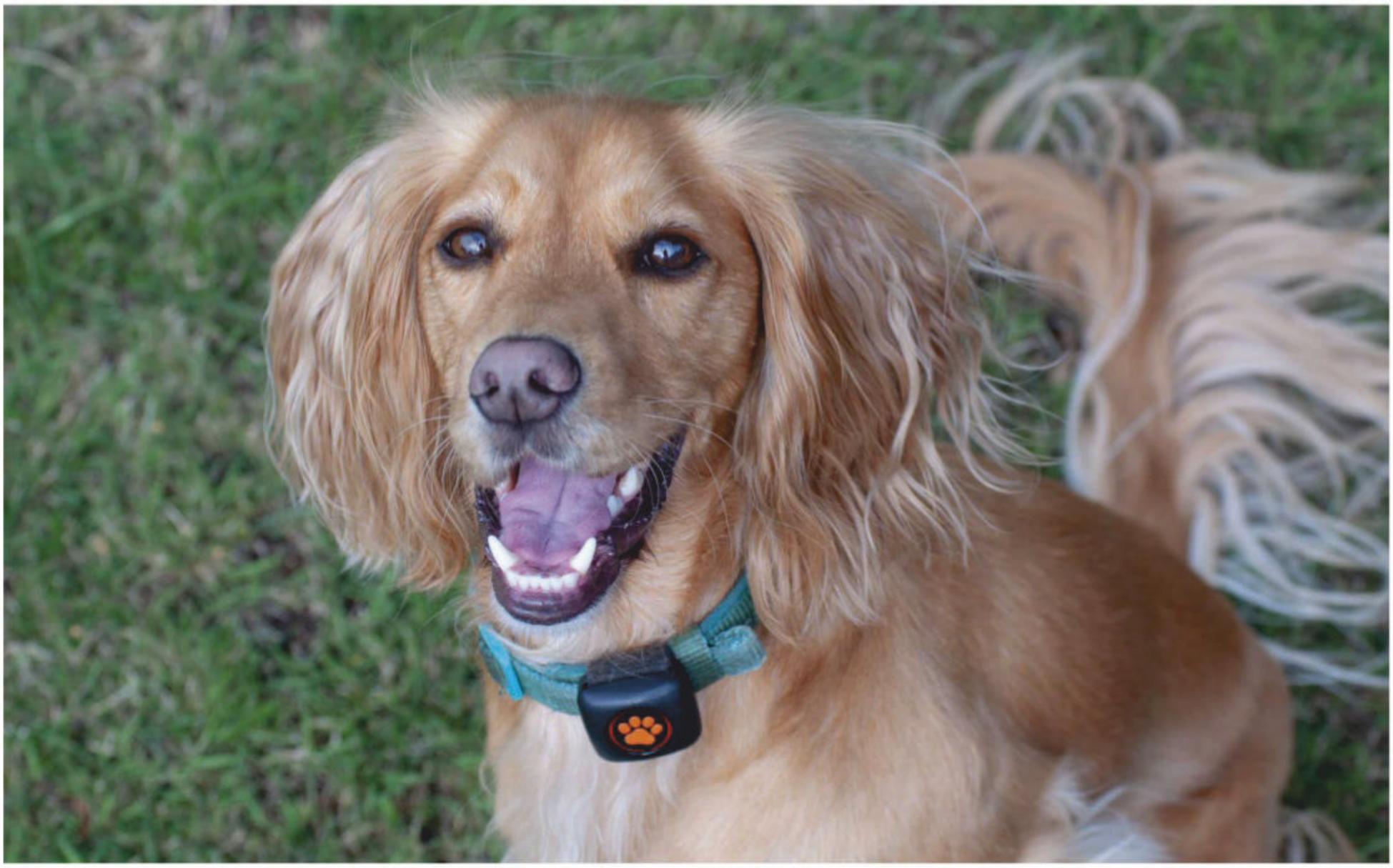
(£20, WEIDENFELD & NICOLSON)

Hey kids, I just want to say on behalf of my generation, I'm sorry. We Millennials, we tried, but it's time to pass the baton over to you if we're going to survive into the next century. That's the message I get reading *The Future Starts Here,* anyway. Through conversations with some colourful characters, the history of *Star Trek*, and the absolute destruction of popular Generation X movie *The Breakfast Club*, the book explains why those of us who grew up in the 20th Century (myself included) have a gloomy view of whatever will be.

Fortunately, all is not lost. As Higgs explains, Generation Z – people like climate activist Greta Thunberg (pictured below) or the survivors of the Stoneman Douglas High School shooting – have just the right stuff to actually make the sort of impact that could end climate change, unemployment and gun violence.

It's not pure science, more social history, but as an exploration on how technology is changing the way we interact with both the planet and the people who live on it, this brilliantly written, and exceptionally witty book is difficult to put down. Despite hammering home how wildly removed I am from Gen Z, *The Future Starts Here* did fill me with some optimism that maybe, things are looking up.

BBC, GETTY IMAGES



WHAT I'M
TESTING

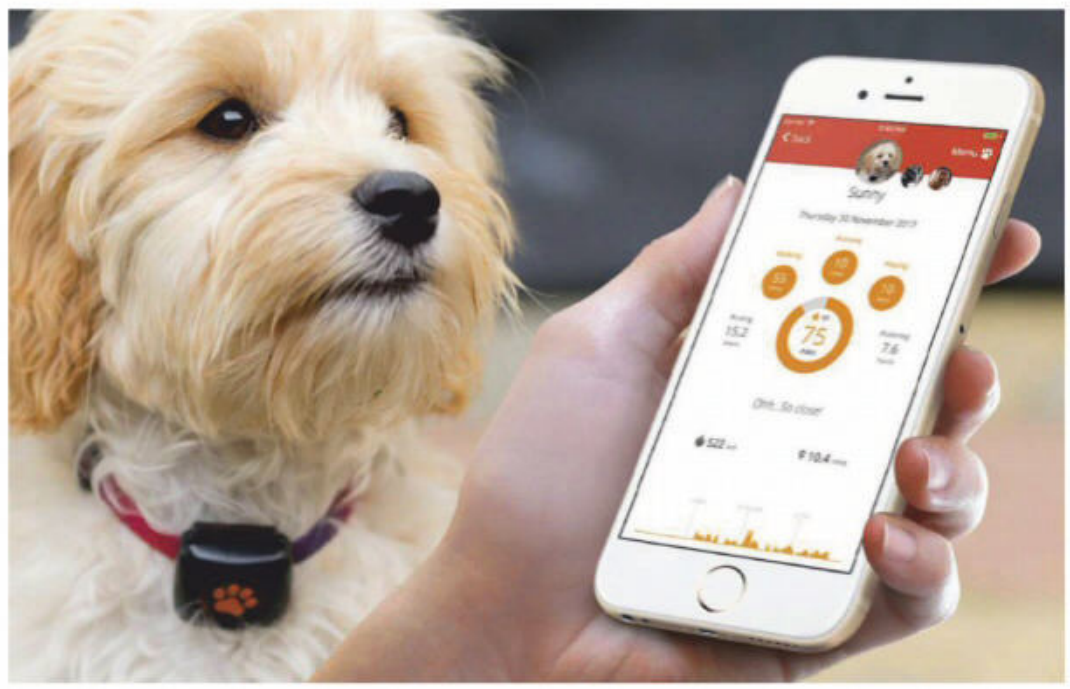
Sara Rigby
ONLINE ASSISTANT

PITPAT2

£39, PITPAT.COM

How much exercise does your dog really need – and how much do they actually get? How many miles do they run on a single walk? I ponder these questions when I let Alfie, my black lab, off the lead and he immediately vanishes over the horizon. PitPat2, a fitness tracker specially designed for dogs, answers with a wealth of data. The device, which connects to a free smartphone app via Bluetooth, tracks how much time your dog spends walking, running, playing and resting, based on a step counter. Alfie normally hates having anything on his collar, but he doesn't even seem to notice the unobtrusive PitPat.

To calculate how much exercise Alfie needs, the app considers his breed, age and weight and produces a daily goal – though you can adjust it.



The PitPat2 fits onto your dog's collar to monitor their activity via an app. The device is waterproof – great news if your pet loves to swim!

In conjunction with your vet, you can even set a weight loss target, and the app will estimate how long it will take for your pet to achieve it.

A paid version of the app, called *PitPat Life*, comes with discounts on various dog products and gives you the ability to earn points to exchange for dog toys and merchandise, though it doesn't add any extra data or features.

Now I know his daily goal, I'm not sure that tracking Alfie's exercise would be particularly useful in the long-term. That said, the app is easy to use and keeping an eye on what he does each day is definitely interesting. Alfie is quite an active dog, so I can imagine that it would be more useful if your pup prefers cuddles to walks. Plus, you can share your dog's data with anyone else who has the app, so I'd be more comfortable with someone else looking after Alfie if I could make sure he was getting plenty of walks while I was away.

DISCOVER MORE

SQUEEZE EXTRA JUICE OUT OF THE TOPICS IN THIS ISSUE OF *BBC SCIENCE FOCUS* WITH THESE BOOKS, WEBSITES AND SHOWS

Eye opener *p6*

ANTI-DRONE GUNS
Watch a live-stream of the Paris Bastille Day parade, where the anti-drone guns were demonstrated in front of thousands. Skip ahead to 35:50 to see the guns in action.
bit.ly/anti_drone_guns

MELTING SEA ICE
Climate scientist Steffen Olsen captured this incredible video of the dogs pulling him across the melting Inglefield Fjord sea ice.
bit.ly/melting_sea_ice

Reality check *p32*

CAT SENSE
BY JOHN BRADSHAW
(£9.99, PENGUIN)
Published in 2014, John Bradshaw's insight into the domestic cat describes the challenges faced by felines, and their owners, in their lifetime.

MAMMAL MAPPER APP
FREE, AVAILABLE ON IOS AND ANDROID
You can help The Mammal Society survey the UK's wildlife populations by recording any sightings of mammals. The library created by users of the app will contribute to future scientific research and help the long-term conservation of mammals.

HOW TO STOP SEAGULLS STEALING YOUR FOOD
To demonstrate that herring gulls could be deterred by the human gaze, researcher Madeleine Goumas from the University of Exeter defends her food at the harbourside. Watch a clip of this strange interaction on YouTube.
bit.ly/seagull_food

Michael Mosley *p59*

IS THERE A RELATIONSHIP BETWEEN CHOCOLATE CONSUMPTION AND SYMPTOMS OF DEPRESSION?
In this science paper, published in the journal *Depression & Anxiety*, the researchers investigate whether eating chocolate can help with depression.
bit.ly/choc_depression

Aleks Krotoski *p60*

YOU AREN'T AT THE MERCY OF YOUR EMOTIONS
In this TED talk, psychology professor Lisa Feldman Barrett explains how studies and brain scans have given us an insight into emotions. Turns out, we have more control over our emotions than we might believe.
bit.ly/emotional_data

Richard Dawkins interview *p62*

THE FOUR HORSEMEN
Watch Richard Dawkins in conversation with Christopher Hitchens, Sam Harris and Daniel C Dennett, who are collectively known as the four horsemen of New Atheism. They discuss (and sometimes disagree on) science, atheism, evolution and more key questions in the discourse of reason and religion.
bit.ly/four_horseman

FOR MORE, FOLLOW US
@SCIENCEFOCUS

Shock value *p68*

THE MIND IN THE MEDIA
This insightful BBC Radio 4 documentary by author and former psychiatric nurse Nathan Filer explores how the media can shape our perceptions of mental health conditions and their treatments, including ECT.
bit.ly/mind_media

The overpopulation debate *p74*

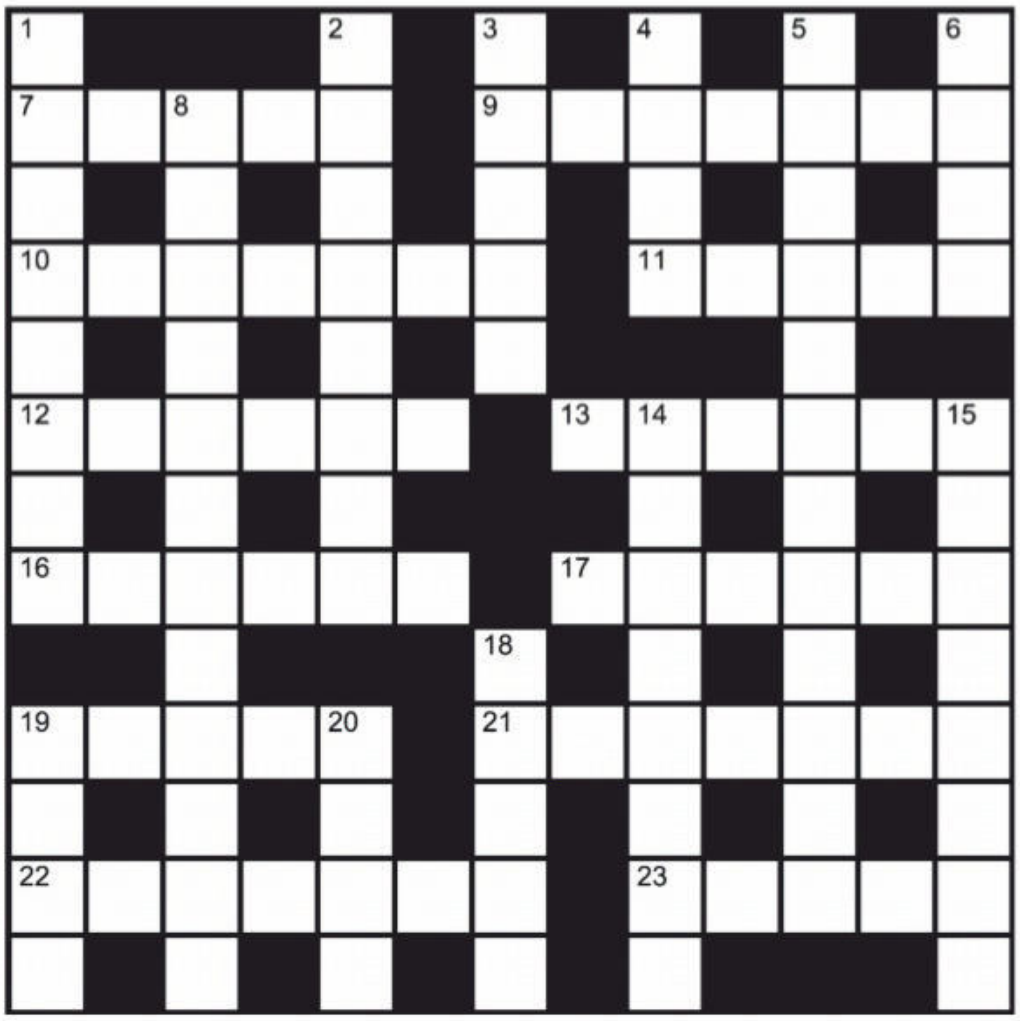
OVERPOPULATION – THE HUMAN EXPLOSION EXPLAINED
This video from Kurzgesagt outlines the Demographic Transition Model in even more detail (complete with cool animation!).
bit.ly/population_explosion

DOES SAVING MORE LIVES LEAD TO OVERPOPULATION?
Here, entrepreneur and philanthropist Bill Gates asks whether saving more lives through improved healthcare will lead to a population explosion.
bit.ly/bill_gates_overpopulation

A GLOBAL POPULATION OF NINE BILLION IS SUSTAINABLE
In this episode of BBC Radio 4's *Glass Half Full*, Fi Glover pits optimists against pessimists to debate whether a global population of nine billion is sustainable.
bit.ly/population_glass_full

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

7 A large storm left out some plants (5)
9 Sailor finds a single mollusc (7)
10 One lion circling around doctor, undecided (2,5)
11 Go on at a student about a river (5)
12 Slow tempo, going round a shelter (4-2)
13 Enjoy getting different set to break down (6)
16 Put the lid on a drink (6)
17 Firm yet careless with old animal (6)
19 City-dwellers initially smell a stream (5)
21 Perception is near at hand (7)
22 Still during key part of the day (7)
23 Adorn new red ship (5)

DOWN

1 Head of biology I call about American cause of disease (8
2 Man with metric solution that's airtight (8)
3 Sausage without the Spanish cabbage (5)
4 France formerly reported resentment (4)
5 Style of piano-playing in rhyme (6-6)
6 Gas from underdone onions (4)
8 Gauge broadcast, manage revolt (12)
14 Press team to join old warship (8)
15 It's a tree, generating paper (8)
18 Slob in goal has a game (5)
19 Cut in personnel (4)
20 Use needles, needles first found in equipment (4)

GETTY IMAGES

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

COVER STORY

MICROBES AND YOU

How you can eat your way to happiness.

PLUS

SHOULD YOU UPGRADE YOUR BRAIN?

The age of the cyborg is coming.

AVERTING ARMAGEDDON

Get Bruce Willis on speed dial! We find out more about the AIDA mission, which is going to launch into space in 2020 to smash into an asteroid.

ON SALE 25 SEPT

SF

A SCIENTIST'S GUIDE TO LIFE

TIME TO REST

AS THE RUGBY WORLD CUP LOOMS LARGE, EXERCISE PHYSIOLOGIST **JOE COSTELLO** EXPLAINS HOW BEST TO RECOVER AFTER A HARD WORKOUT

HOW VITAL IS IT TO ALLOW RECOVERY TIME?

Very. If you're a recreational non elite athlete and you train for seven days without taking a break, you could develop symptoms of overtraining, such as fatigue, soreness and immune system dysfunction. Taking at least one rest day over the course of the week is essential.

Pro athletes in a competition may not get a say in the amount of rest they can take. With the Rugby World Cup, for example, there's a defined window during which the players will compete so this dictates the rest time they can take between games. Often the optimal rest versus the practicality of what they can actually take is different.

HOW MUCH SHOULD I DRINK?

Weigh yourself before and after your workout. If you haven't eaten or drunk anything while exercising, the difference will be the mass you have lost via sweating. It's a good indicator of your hydration status. A litre of water weighs one kilogram, so if you've lost a kilogram, you need to drink at least a litre of water.

WHAT SHOULD I DRINK?

You often see people on the treadmill with calorie laden commercial sports drinks. The problem is that they could be consuming more calories than they are expending by exercise. If you are exercising for less than an hour then water is all you need. If, however, you are training for several hours at a time then you will be losing electrolytes in your sweat. For every litre of sweat produced, you lose around one gram of sodium, so then it may be sensible to have a drink that contains some of these electrolytes.

WHAT SHOULD I EAT AFTER A WORKOUT?

It's a good idea to eat 20g to 40g of high-quality protein within an hour or so after a workout. High-quality proteins, like fish, eggs or dairy products, are essential for muscle protein synthesis, which is the process of building muscle mass during recovery.

ARE PROTEIN DRINKS ANY GOOD?

They're no better or worse than eating a natural source of protein. They're just more convenient. I caution people from switching to them entirely because natural food offers many additional nutrients. It's important not to replace your meal with shakes.

SHOULD I STRETCH AFTER EXERCISE?

We've all heard a trainer say that you need to stretch after exercise or be sore the next day, but there's no evidence to back this up. We can say pretty conclusively that stretching before, during or after exercise makes no difference to the soreness you experience.

CAN SUPPLEMENTS AID RECOVERY?

We did a systematic review on this and found that both antioxidant supplements and natural antioxidants have no meaningful effect on soreness or performance after exercise. The important take-home message is this. Extras like stretching, taking supplements or having an ice bath typically only infer between 1 per cent and 2 per cent of an advantage, if any at all. 'The three Rs': rest, rehydration and replenishment should make up 99 per cent of your recovery. **SF**

DR JOE COSTELLO
Joe is an exercise physiologist at the University of Portsmouth.
Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

Rest days are important, so don't sweat it out seven days a week.

2

Eat a bit of protein after a workout, but you don't need to splash out on pricey shakes.

3

Stretching doesn't stop soreness, despite what your trainer says.

ILLUSTRATION: VICTOR SOMA

Thank you, Sylvia

Sylvia left a gift in her Will to help conquer Stroke

The first we knew of Sylvia was when we received notification of the gift she'd left us in her Will. Shortly after, a beautiful story of a much-loved woman began to unfurl.

Friends remembered Sylvia's kind-heart and her wish to help others. She spent part of her adult-life caring for her mother, and developed a passion for medicine. Becoming a medical secretary was her next step and, in the course of her career, she discovered the devastating impact a stroke could have on people and their families. She saw that research and treatment were vastly under-funded, and she decided to remember the Stroke Association in her Will.

Sylvia's gift has helped fund our work to conquer stroke. She's supported research to prevent and treat stroke, and she's helped care for survivors. And that's something you can do too – in the same way.

If you would like to learn more about remembering the Stroke Association in your Will, please get in touch.

Call 020 75661505 email legacy@stroke.org.uk or visit stroke.org.uk/legacy

Stroke association

FUJIFILM

MASTERS OF COLOUR

Over 80 years of experience in photography goes into every camera we make. It's part of what makes the FUJIFILM X Series special

FUJIFILM-X.COM

IMAGE TAKEN BY UK X-PHOTOGRAPHER MARIANNE CHUA